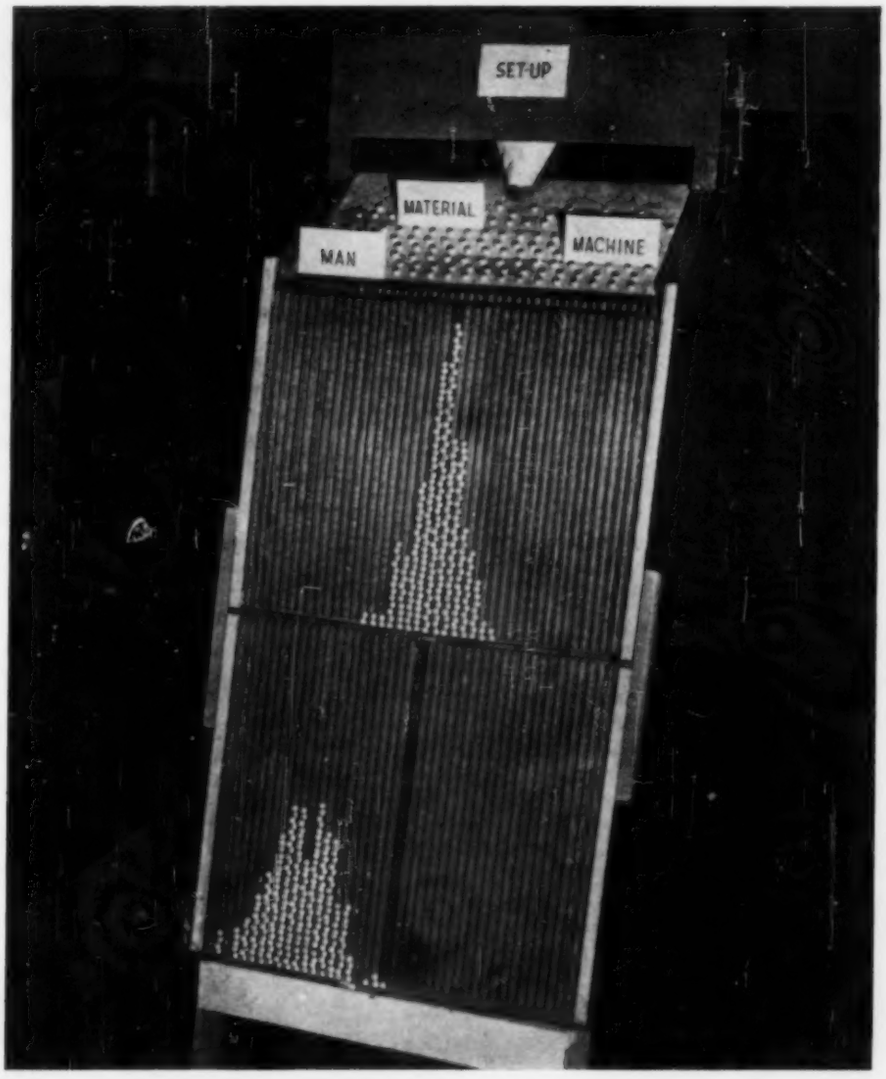
Industrial QUALITY CONTROL

VOL. III NOVEMBER, 1946 NO. 3



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FUTURE MEETINGS OF LOCAL SECTIONS

Delaware Section — at Wilmington

January 2, 1947:

"Classification and Calibration of Ammunition in the South Pacific," Mr. O. P. Bruno, Ballistic Research Laboratory, Maryland.

February 6, 1947:

"Fundamentals of Sequential Analysis," Mr. E. M. Schrock, Aberdeen Proving Ground, Maryland.

Philadelphia Section — at Temple University

December 13, 1946:

"Applications of Quality Control by Statistical Methods," Mr. W. J. Masser, General Electric Company.

January 16, 1947:

"The Significance of Modern Quality Control to Management," Mr. A. I. Peterson, Radio Corporation of America.

Metropolitan New York Section

December 13, 1946:

Robert Treat Hotel, Newark, New Jersey.

December 14, 1946:

Princeton University (Details on page 27).

January 24, 1947:

Hotel Essex House, Newark, New Jersey.

Southern Tier Society for Quality Control

The first dinner meeting of the Society was held in the American Legion Hall in Binghamton, N. Y., on Tuesday evening, 22nd October, 1946. About eighty members and guests were present.

The dinner was followed by a short business meeting during which members were appointed to a number of working committees by President Robert, and Mr. Merlin J. Barret was elected to represent the Society on the Board of Directors of the American Society.

Mr. G. D. Edwards, President of the American Society for Quality Control, was then introduced as the speaker of the evening. He had chosen as his subject: "Quality Control And What Our Societies Can Contribute To Its Advancement;" and his remarks were enthusiastically received by all present.

Industrial Quality Control

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INDUSTRIAL QUALITY CONTROL

Published Bi-monthly
by the

AMERICAN SOCEITY FOR QUALITY CONTROL
Inc.
305 East 43 Street
New York 17, N. Y.

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New York, N. Y.

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Correspondence is invited on all controversial matters.

General Information

INDUSTRIAL QUALITY CONTROL is published in January, March, May, July, September, and November, and is mailed to all members of the Society as one of the privileges of membership.

Direct Subscriptions to INDUSTRIAL QUALITY CONTROL will not be accepted from individuals. However, Subscriptions to the magazine will be received from Libraries and like institutions at five dollars per year. Remittances must be in United States funds and should be sent directly to the Treasurer of the Society.

Membership in The American Society for Quality Control is available through local society Sections or directly through the Executive Secretary. Annual dues are five dollars for direct national membership. Information concerning local societies may be obtained from the Executive Secretary.

Founding Membership in the Society is available prior to July 1,

Membership in the Society is personal and professional, and is not open to corporations, companies, or other organizations.

Contributions to the Society for the support of its activities will be accepted from corporations, companies, and others.

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COST OF BACK ISSUES

Most back issues can still be supplied individually at $1.00 each, but certain issues are now available only in complete volumes.

Volume I, which includes the July, 1944, September, 1944, November, 1944, January, 1945, March, 1945, and May, 1945, issues, is available at a price of $5.00. Volume II, which includes the July, 1945, September, 1945, November, 1945, January, 1946, March, 1946 and May, 1946 issues, is also available at a price of $5.00.

INDUSTRIAL QUALITY CONTROL
was founded in 1944 by the
SOCIETY OF
QUALITY CONTROL ENGINEERS
BUFFALO
in cooperation with
THE UNIVERSITY OF BUFFALO

FOURTH REPORT OF MIDWEST Quality Control Conference

Quality Reporting---Putting Inspection Results to Work

HAROLD R. KELLOGG

WESTERN ELECTRIC

[**Clinic 20**]

Quality reporting is an integral part of the general inspection problem. It cannot be divorced from the logic and aims of an overall inspection program. A discussion of quality reporting should therefore include consideration of

(1) inspection procedures, including the collection of data;

(2) appraisal of the data;

(3) reporting and publicizing results.

This outlines the program as it will be discussed in this paper. However, the above three phases are not separate and distinct and should not be so considered. They are intimately related, and cannot be considered independently by those who are interested in publicizing inspection results.

Consider the analogy of quality reporting to news reporting. Publication of a paper such as a small town weekly, a metropolitan daily, or the Wall Street Journal requires an overall policy that determines the type of news which the paper will supply its readers. The entire organization is geared to this policy; reporting, editing, and publishing are guided by a single objective. An inspection unit must also determine the type of quality news that is of value to suppliers, operators, engineers, managers, and customers, and it must establish an inspection program for collecting this news. The collection, the editing, and the reporting must be coordinated toward a common goal.

An efficient newspaper will not spend time and money gathering reams of news it never intends to use. Neither will an efficient inspection unit. Each inspection is a continuing source of quality news which can be exploited by relatively inexpensive analysis and distribution. It is therefore wise to consider the possible uses of results before the inspection is undertaken—that is, while the inspection is being planned. Inspections are necessary but costly; they will be a much better investment if they are preceded by a little additional thought directed toward putting their results to effective use. Planning for quality reporting supplies this direction.

Inspection Procedures Including Collection of Data

A good sports reporter understands the sporting events that he covers. He watches each closely and carries away an accurate record of what he sees. By the same token, inspectors must understand, and inspection procedures must be geared to, the manufacturing program whose performance they are covering.

Inspection must be sound. If a given inspection does not yield reliable results, the results should not be made the basis of a news story on quality. To get reliable results it is necessary that gages and testing equipment be accurate, that inspectors make the prescribed test on the prescribed sample in the prescribed manner, and that the prescribed manner shall have received enough initial thought to insure valid inspection results.

Along this same line is the necessity that the whole inspection unit be guided by a basic definition of quality. Under the modern concept of quality, the design engineer specifies a requirement with a plus and minus tolerance, and quality is thought of as varying within limits around a specified mean. Quality is defined in a statistical or operational sense—statistical because it is thought of as being distributed about an average, operational because it is thought of as having a functional meaning which can be tested. If this objectivity is fully appreciated, inspections will be much less subject to the moods, fancies, or opinions of the inspector.

With modern inspection based on an objective meaning of quality the task of the results man becomes that of describing fluctuations in quality and reporting them to the interested persons.

The Appraisal of Data

The statistical tools available for extracting information from a set of data need not be discussed here and can be passed over with the observation that such tools are available and can be adapted to almost any situation without incurring unwarranted expenditure for clerical effort. These tools, properly set up by a statistical engineer, can be used as a matter of routine by clerical talent. Special studies, of course, call for the services of the engineer, but the cost

consuming routines can be operated by a clerical staff. Let us focus attention here on a consideration of the type of news that inspection results contain.

The primary use for results of a given inspection should be evident from the purpose of the inspection. The first use of results from an acceptance inspection is to determine whether or not product is acceptable. Results of a control inspection serve as a guide for the process. However, the value inherent in inspection results frequently goes far beyond this singleness of purpose. Although inspections are made to accept, to control, or to sort, inherent in each is the ability to give some picture of quality characteristics. It is this ability that can be exploited.

There will probably be general agreement that a refined control inspection, conducted on a variables basis as a special engineering investigation, and subjected to treatment by analysis of variance, outlines the operating characteristics of the process and the resulting product characteristics. It exposes the component factors which the process molds into product quality. In doing this, it defines the individual contributions to overall product appraisal that are made by the material, the machines, and the operators.

Inspections of this type, however, are expensive, and if they are made at all they are usually considered justifiable only as a tool to "prove in" a new or a changed process. Fortunately, some characterizing information of this type is contained in many routine inspections, whether by attributes or variables, and is not necessarily an exclusive feature of special engineering investigations. Good quality reporting calls for an appreciation of all the evidence disclosed by each inspection. Much of this evidence lies in the recorded inspection results, and can be inexpensively extracted by a proper classifying and tabulating approach.

In the telephone industry, for example, the quality of soldered connections is of particular interest. The routine classification and tabulation of soldering defects can be such that the inspection will provide a continuous picture of the manner in which insecure connections, unsoldered connections, cold solders, and other soldering defects are detracting from the quality of soldering operations. A soldering inspection is an attribute test, yet the inspection results, properly classified, and interpreted by a quality reporter with a knowledge of the soldering operation, point in turn to a careless operator, a defective soldering iron, which in this case is the machine, or to defective solder, which is the raw material.

Inspection results for all of the products inspected by the quality control organization at Western Electric are classified and tabulated so that they provide a running picture of quality for the electrical characteristics, the mechanical characteristics, and the assembly items of each product. The classification is made by the inspector, and the tabulation by a small results group which periodically reviews the data for news stories on quality. The inspection objective is to provide quality assurance and quality news, and the inspection program is designed to accomplish this objective.

Routine inspections frequently furnish valuable information for the product design engineer. The Bell Telephone Laboratories, which design all of Western Electric's products, receive regular reports of the results of variables inspections made by the latter's quality control inspectors. This information is used by Western Electric as a check on the process and by the Laboratories as an aid to product design and development.

Routine inspections also yield information for the process planning engineer. For example, a recent process change at Western Electric was suggested by the results of a routine inspection. A girl in one of the assembly lines was performing two operations—one requiring skill and the other, an unskilled operation, was, over a period of hours, physically fatiguing. Inspection results indicated that toward the end of the shift the unskilled operation was interfering with the proper performance of the more skilled operation. The process has been rearranged so that the unskilled operation is performed by another operator in the assembly line.

Any inspection (and this is particularly true of an inspection made on a variables basis) that provides measurements of the character of finished product, the character of the mechanical or the manual portion of the process, or the character of raw material is a continual source of quality news of interest to the design engineer and the process engineer.

The production scheduling group might well be interested in information on the performance of various machines so that it can schedule the more critical jobs on machines having the best performance records. Utilization of this type of information tends toward a better product, a better process, and reduced manufacturing costs, and, since it is supplied by the inspection agency, it increases the value of the inspection.

Information on the character of purchased material is an item of interest to the purchasing department. Ordinarily this information comes from a purchased material inspection and is regularly brought to the attention of the interested purchasing agent. Frequently, however, the intimacy of manufacturing experience, including process and final inspections, reveals material characteristics that have escaped detection by the more objective purchased material inspection. If the noted characteristics cause only moderate manufacturing difficulties, they may never be brought to the attention of the supplier. This can be avoided by emphasizing to the manufacturing department the value of reporting all instances where material deviates from specifications. The supplier may thus be able to avoid more serious deviations.

Information on the character of a process might also be of interest to the accounting unit. Modern accounting which deals with such concepts as standard costs, controllable costs, and cost estimates, might make valuable use of up-to-date information on the fraction defective that may be expected from a given process.

Information on the character of the manual portion of a process might be an item of interest to the pesonnel department. Inspection results which reveal the types of errors individuals make on a given job help determine the type of individual that should be placed on that job. Modern methods of per-

sonnel placement, personnel training, and aptitude testing are based largely on past experience. Consideration might well be given to the possibility that experience of this type can be revealed by inspection results. For example, there is the case of a personnel man who requested that he be furnished with the results of a certain inspection. He tabulated them for a few weeks and noticed that operator's mistakes were more prevalent among the men than among the women operators. It was decided that only women operators should be placed on this particular job.

All this is not to suggest that the personnel, the accounting, or the purchasing departments be deluged with routine inspection results. It is to suggest merely that the value of finding and reporting news of this kind ought to be more fully appreciated.

Publicizing Results

A quality report, like a newspaper, should be issued on a regular, dependable schedule. This is particularly true of reports to management which is interested in overall, average quality. Line operators can usually best be informed of the results of a given inspection by a memorandum or direct contact from the inspection group. Such vehicles move with dispatch, and speed is usually the essence of reporting inspection results to the people who are molding quality.

Reports to management, however, are in a different category. These reports should, like a newspaper, make use of a standard format which sets them apart from other reports. They should be attractive in appearance and issued on schedule. They do not necessarily require expensive printing or reproduction facilities, but their value is enhanced if they invite attention and furnish only information which gives management vital quality news unencumbered by detail.

The report ought also to be so designed that it gives emphasis to those quality situations most in need of attention. The quality control organization at Western Electric meets this problem by issuing, each month, a report covering only those products whose average quality for the month is below that normally expected for the product. This report goes to top management and shows, in control chart form for each product covered, a comparison of the product's past quality record with any current adverse quality rating. Recorded on each chart is a concise description of those defective conditions responsible for the current below-normal quality rating.

In addition to reports of this type, particularly serious or persistent defect conditions can sometimes best be handled by a memorandum to high level supervision. Such memoranda, if used wisely, can be very effective. During the initial war effort at Western Electric, high level memoranda were used exclusively for reporting quality to top management. The memoranda were direct and to the point, and the recommendations they made had a gratifying way of filtering down through the operating line.

Preparation of a quality report which covers a variety of different products poses a problem of compromise between detail and summary that is anything but easy. It is obviously impractical to publish long pages of raw data or page after page of control charts, each for a single product characteristic. In some cases this would run to thirty or forty control charts per product. Fraction defective charts are limited in the same way. They are not adequate for reporting the overall quality of a product whose conformance is dependent on meeting a number of different requirements.

Western Electric, under a product shop arrangement, has a number of distinct shop organizations headed by superintendents who report to a division manager. At each works location are several division managers who report to the works manager. Each of these men is responsible for the quality of products manufactured in his organization, yet the breadth of his interests and the volume of his work are such that he cannot spend time with detailed inspection results. These men are interested not in lot by lot quality or the quality of a single characteristic, but rather in overall quality. They want to know how the quality of products for which they are responsible stacks up; how well the quality of each product is controlled; how well each meets its individual requirements; how the quality of a product manufactured in one organization compares with the quality of the same product from one of the other organizations or one of the other works.

At the same time the intermediate levels of line supervisors expect quality reports to help them with such questions as: What requirements are not being met? . . . What process may require closer supervision? . . . When should line inspection be increased or process engineering introduced because of indications of lack of control?

First level line supervisors are in constant contact with the operating process; they deal directly with inspection, and they know what is going on. Consequently quality reports at Western Electric are aimed at top management and intermediate line supervisors.

Here then is the problem: given many different products for each of which quality is measured by the manner in which it meets its several requirements, it is required to report inspection results in such a way as to aid operating supervision by pointing out defective quality conditions, lack of control, or quality trends and at the same time be sufficiently clear and concise to answer for management such questions as the following. Is the overall quality of product A satisfactorily controlled? How does the present quality of product A compare with that of a month ago? Three months ago? A year ago? Is there any general trend in the quality of product A, either upward or downward? How does the overall quality of product A compare with the overall quality of product B? How does the quality of product A_1, manufactured by Department 1, compare with that of product A_2, the same product manufactured by Department 2?

Presentation of a simple quality picture for manufactured products is also complicated by the varying degrees to which the quality of different products may be affected by the same defect. In telephone products, for example, where it is desired to grade or rate the quality of such widely different products as a telephone receiver and a lead covered cable, it is not possible to say that a given amount should be subtracted from a perfect quality

rate if the product finish or surface is nicked, because a very minute surface nick on a receiver diaphragm seat may render the unit unfit for service while a more serious degree of this same defect, a surface scratch for instance, in a telephone cable will in no way effect the serviceability of the cable. Furthermore, inspection results may show a unit of very expensive product, a large vacuum tube for example, to be totally unfit for use and a unit of an inexpensive product—a small switchboard lamp—totally unfit for use. How should these defects affect the **average** quality rating of these two products? Are these equally serious quality conditions?

In order to provide a quality picture that will answer these questions, it has been found necessary to legislate that the quality ratings of each product shall be dependent only on the seriousness of defects occurring in that product—seriousness in turn to be dependent only on the effect the defect has on that product. In other words, a defective unit is a defective unit regardless of its cost or complexity.

Having determined that it is equally important for every product to meet its specifications, let us consider some inspection results and see what can be done with them. As an example, consider a dial from a telephone set. This is an assembly of a number of small piece parts. The dial is inspected for three types of items: electrical, dimensional, and assembly items with a number of different requirements in each category. Inspection results gathered over a period of time provide a defect distribution for each requirement. These are tabulated inspection results. They do not reveal much about quality. We could, of course, compute an average fraction defective for each requirement, and a standard deviation, and plot the results on a control chart. However, such a procedure would lead to a host of control charts and would give little comprehensive information about the quality of the average dial as a unit. Similar control charts for other products would, in the aggregate, be little more than a mass of burdensome information. What is needed is a common denominator that can be applied to each requirement and summarized to give a single index of quality for dials that can be compared with similar indices for other products or for dials manufactured during an earlier period.

At Western Electric this common denominator is called a **demerit.** Inspection results are translated from defect descriptions to a numerical demerit value that indicates the seriousness of the defect. In order to do this, defect seriousness is classified according to the following four-fold classification. (Other classifications could be used, but this is one that has been found readily adaptable to telephone products.)

Class "A" Defects—Very serious.

Class "B" Defects—Serious.

Class "C" Defects—Moderately serious.

Class "D" Defects—Not serious.

Every defect occurring in an inspection sample fits into one or another of these classifications. The translation of defect description to numerical demerit value is accomplished by assigning a standard number of demerits to each defect of a given class. Since this is merely a relative weighting operation, only the relative demerit weights are of importance, and the scale of demerit may be chosen arbitrarily. At Western Electric weights of 100, 50, 10, and 1 for Class A, B, C, and D respectively have proved satisfactory. For each defect occurring in the inspection sample 100 demerits are charged if the defect is of Class A seriousness, 50 if it is Class B, and so on. This is an easy operation to carry out because once the plan is set up the demerit assessment will be done automatically by the inspector at the time he records the defect.

Suppose that in a sample of 100 dials defects are found whose demerit weights total 75. It is then very simple to compute a **demerit per unit** value which is an index of quality for all dials represented by the sample. In this case it is 75 divided by 100 or .75 DPU. This is an index based on the complete inspection of each dial in the sample. Similar indices can be prepared for other products. Daily, weekly or monthly summarization of the demerits assessed against each product will show that dials for the day or week averaged .75 DPU, while cords averaged .3 DPU, vacuum tubes averaged 1.0 DPU, and so on.

By analyzing past inspection results it is possible to find the number of demerits per unit that, on the average, occur on dials, on lamps, on tubes, and on telephone sets. These DPU values can be used to construct a variables control chart. Subsequent DPU values can be plotted on this chart. There then exists but one control chart for each product. These charts can be circulated periodically to the higher levels of management. They give a concise picture of the quality of the product.

In classifying defects in this manner some detail is undoubtedly lost. However, the DPU index provides a practical method of describing quality, and in cases of unfavorable q u a l i t y conditions which are specifically brought to the attention of management, the DPU value can be accompanied by a summarized description of defects so that the quality rating and the nature of the trouble are both portrayed. In addition, detailed inspection results are circulated to shop supervisors and are always available for investigation of inquiries prompted by the DPU quality ratings.

This method of rating quality has been in use at Western Electric for over fifteen years. It provides a very effective compromise between detail and s u m m a r y. Through its use quality reports provide headlines for the headline readers and detail for the text readers. The reports are at once current and historical; they are concise and informative. They put inspection results to work at all levels of supervision.

Mr. H. F. Dodge of the Bell Telephone Laboratories has described this index very well in an article which appeared in the April, 1928, issue of the "Bell System Technical Journal." In this article Mr. Dodge also explains the mathematics involved in the computation of limit lines for a weighted average.

Summary

1. Be sure the results of inspection are reliable before attempting to draw any quality conclusions from them.

2. Do not spend the time and money to collect and tabulate inspection results unless it is the in-

tention to analyze them thoroughly. This analysis should cover not only evidence which is immediately apparent, but should be extended to explore what hidden evidence of value lies within the data.

3. The success of quality reporting depends upon an appreciation of the different needs of line supervisors, top management, and others, and upon presenting the information to each in the form in which it will be of maximum use.

One final thought that should be especially prominent in the minds of those who are interested in publicizing inspection results: one of the biggest contributions a quality control organization can make is to establish and maintain for itself a plantwide reputation for reliable, practicable, and unbiased quality reporting.

Farmall Quality Control Training Program For Shop Supervision

J. E. RAHN

FARMALL WORKS. INTERNATIONAL HARVESTER COMPANY

[**Clinic 18**]

In order to obtain maximum benefits from a program of quality control, it is especially necessary that the man in the shop have a workable understanding of the statistical techniques employed and confidence in the new concepts of controlling quality. Dissemination of such information to groups of cynical, practical-minded foremen and supervisors is not as simple as it might first appear. They have a natural antipathy toward new ideas, and especially toward a system based on mathematics. At Farmall we have had gratifying results in solving this problem by use of visual aids and a minimum use of mathematical formulas. Briefly, the program is composed of four, two-hour sessions.

Session I—Management Session

This session is called by top management for the purpose of introducing the system to the department heads and general foremen. The major part of this session is devoted to general remarks by top management concerning use in industry of quality control methods, and a round table discussion of current quality problems. The second portion of this session is devoted to showing each department head **why** he should be interested in a new and vital approach to controlling quality. The "economic aspects of maintaining quality standards" is presented by means of wall charts; each department head is shown the economic repercussion from scrap and rework on his budget system.

The primary purpose of the management session is to emphasize that the new system is being sponsored by management.

Session II—Introduction to Probability Curve

The frequency distribution, the normal probability curve, and their relationship to shop processes are brought out in this session. The use of blocks, charts, and demonstration board makes it possible to present the significance of these statistical concepts in an easy and understandable manner. A "pile-up" of blocks in a normal curve frequency pattern outlines for the supervisor a "picture" of his process, if it is in control.

The following ideas are illustrated, emphasized, and discussed.

1. The presence of a tall pile or dominant dimension represents the frequency at the average or "set-up" level.
2. There is a well-defined tendency for the piece parts to cluster about the "set-up level."
3. The spread of parts from the "set-up" level denotes the variability in the process.
4. Division of a normal process pattern into "chance" zones:

$$\frac{\text{X-Max.} - \text{X-Min.}}{6} = 1 \text{ chance zone.}$$

5. Percentage breakdown by chance zones in the ideal case:
   ± 1 chance zone from set-up level includes 68.26% of total production;
   ± 2 chance zones from set-up level includes 95.5% of total production;
   ± 3 chance zones from set-up level includes 99.73% of total production.
6. Chance of an individual point exceeding a chance zone on one side or the other of set-up level, if process is in control.
   Odds are about 2 to 1 against a part exceeding 1 chance zone.
   Odds are about 21 to 1 against a part exceeding 2 chance zones.
   Odds are about 370 to 1 against a part exceeding 3 chance zones.
   Odds are about 16,000 to 1 against a part exceeding 4 chance zones.
   Odds are about 1,740,000 to 1 against a part exceeding 5 chance zones.
7. Construction of control limits from ± 3 chance zone limits.

Session III—Testing for Control of A Process

In this session the $\overline{X}$ and R variables are introduced as "measuring sticks" for the process, $\overline{X}$ denoting the level of quality and R the variability in quality. A control chart is constructed by using the sum of three dice (man, machine, and material) as representative of a part measurement, accumulating an average and range for every five throws, and recording these data on the control chart.

The American Standards Association formulas are applied to the $\overline{X}$ and R data from the dice process, and the significance of the control limits is shown by introducing a "loaded" die. The presence of an assignable cause immediately becomes apparent on the control chart.

A helpful relationship is shown by dividing the process spread by six to get the width of one chance zone, or one sigma. For the three-dice process, X-Max. — 18 and X-Min. — 3, so we have

$$(18 - 3)/6 = 15/6 = 2.5.$$

Then, substituting 2.5 in the basic relationship for the standard deviation of averages ($\sigma_{\bar{x}}$) and the standard deviation for individuals (σ_x), we get

$$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{n}} = \frac{2.5}{\sqrt{5}} = 1.118$$

so

$$3\sigma_{\bar{x}} = 3.354$$

This value is compared with the control limits obtained by using the R of the dice process. The agreement between theory and observation is usually very close.

It is stressed that with a small number of pieces (twenty samples of n — 5) the frequency distribution will generally not be symmetrical about the average or set-up level, nor will the maximum and minimum pieces representative of the process capability limits always be present. The product variability will be reflected by the average range of the several groups.

An extensive use of visual aids is made in this session to bring out the significance of the statistical concepts involved.

Session IV—Process vs Specifications

In this session the supervisor is shown how to answer the following questions by statistical analysis.

1. Is my process capable of producing 100% acceptable material?
2. How much scrap and rework must I expect to get from my process?
3. Is new equipment necessary for my process?
4. What is the optimum level of operation?

It is shown how the normal curve area table can be used to provide a factual basis for answering such questions when they are considered in the light of striking an economic balance between predicted scrap loss and cost of contemplated process changes.

An efficient visual aid is utilized in this session. (See Front Cover.) The device consists of three main parts: the bead hopper, the process panels, and the measurement compartments.

The bead hopper consists of forty upright tubes, each tube holding ten, 3/8" diameter, beads. At the bottom of each tube is a sheet metal strip which, when retracted, allows ten successive beads to drop through the spout of the hopper and fall at random through the "process." The hopper can be moved to any horizontal position by sliding it along the cross piece. The various positions of the hopper correspond to various set-up, or $\bar{\bar{X}}$, levels in the process, and the setting of the hopper at some chosen level is a basic adjustment in operating the device.

The process panels—man, machine, material—are each 3" wide and 21" long. Each panel contains three rows of staggered pins. In each row the distance between the vertical centerlines of the pins is constant, and the distance between the horizontal centerlines through the pins from row to row is also constant. When the panels have been set in some desired position, and the hopper is moved right or left of a zero position, the arrangement of the pins beneath the hopper spout remains the same (identical process variability), but the set-up level is then above or below a zero position. The panels can be interchanged and/or shifted as much as ½" to the right to simulate process changes. By shifting the panels in various ways, assignable causes are readily introduced into a given process.

The measurement cells are separated into an upper and lower compartment enclosed by plate glass. Each compartment has forty cells, each cell being 19" long with square cross section 7/16" along an inside edge. The zero cell and every fifth cell is painted red to facilitate the measurement of the beads as they drop into the various cells. A spring trap separates the upper and lower compartments. A sample of five or ten beads is accumulated in the upper compartment, measurements recorded, and the beads dropped by retracting the spring. A second spring trap at the bottom of the lower compartment allows the beads to drop into a return hopper.

In the Cover Picture, the lower compartment shows a process for which $\bar{\bar{X}} = -10.45$, $\bar{R} = 8.8$, and $3\sigma_x = 11.3$, based on samples of five.

This particular process pattern was obtained by having all process panels set on a common centerline and moving the set-up hopper ten units to the left of its zero position. The upper compartment shows the "improved" process for which $\bar{\bar{X}} = 0$, $\bar{R} = 5.95$, and $3\sigma_x = 7.65$. The improvement was effected by shifting the material panel ½" to the right and moving the set-up hopper to its zero position.

Instruction time required to teach supervisors and inspectors the relationship between the normal probability curve and $\bar{X}$ and R charts has been greatly reduced by using this device, which was designed to illustrate actual conditions encountered in the shop. In a very short time trainees can see the meaning of such terms as set-up level ($\bar{\bar{X}}$), process variability (R), averages ($\bar{X}$), process capabilities ($3\sigma_x$), out of control processes, assignable causes, and so on.

For each bead process an arbitrary specification is set up prior to obtaining samples. From the $\bar{R}$ of the process the theoretical scrap is predicted. This figure is then substantiated by an actual distribution of 800 beads, which provides a practical demonstration of the use of the normal curve area table. It is stressed that the ultimate refinement of a process depends upon the latent capabilities of man, machine, and material, and that a satisfactory process at an unsatisfactory level may produce as much scrap and rework as an uncontrolled process.

The four sessions are suitable for the majority of the supervision, although special topics and further study is encouraged in the inspection division. Special classes are also held for quality control investigators and observers in which p charts and acceptance sampling techniques are explained. A cartoon booklet and a story concerning the introduction of quality control methods into a screw machine department have also been developed for distribution to the foremen in the processing departments.

Some Methods for Selecting and Training Personnel In Statistical Quality Control

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[**Clinic 9**]

The success of any quality control program is entirely dependent upon its intelligent application to the problems of industry. The theory and knowledge of statistical quality control will, of itself, accomplish nothing; it will not reduce the quantity of scrap by one piece, nor cut costs one cent. It is apparent, therefore, that the successful application of quality control depends upon the ingenuity and knowledge, or know-how, of the personnel engaged in using this important new management tool. The problem of selecting and training personnel in quality control work is therefore probably more important than the actual application of the program itself. This point cannot be stressed too strongly; the success or failure of any quality control program will depend entirely upon the care and time that is originally spent in the selection of personnel and upon an adequate training program.

The complete personnel field dealing with the selection and training of people for work in this, or any other endeavor, is a vocation in itself, and any attempt to cover the multiplicity of problems encountered in various industries would require discussion beyond the scope of this paper. Further, the exact manner of selection and training will depend upon the administrative policy of a particular organization as well as upon the type of business in which the company is engaged, the organizational set-up, and the peculiar problems of the industry. The ideas and statements that follow must be of a more or less general nature, but in most cases can be amplified or modified to meet individual problems. It might be stressed, however, that the general methods that are outlined here have been, and still are being, applied successfully by many firms. Theory alone will have no place in this discussion.

First, then, let us consider the problem of finding individuals who might fit into a statistical quality control program. One of the first and most important qualifications to think about is experience. A number of other considerations will, of course, automatically suggest themselves in connection with any plans that one may have with reference to the employment of people who are going to do the actual work involved in a quality control program. Experience, however, is certainly a consideration of foremost importance.

Statistical quality control work is comparatively new, and there are few trained men available. Experienced quality control men who also have other desirable characteristics necessary for a position of a supervisory nature are extremely hard to find. However, with a little luck, one such person can generally be found. In addition to knowledge of quality control techniques, it is desirable that this individual have experience in the line of work, or at least in the field, in which he is to function. Obviously, it is much better if he is also experienced in one's own plant. Therefore, it is wise (and generally possible) to find a sufficient number of employees with the necessary personal characteristics and educational background in one's own plant to provide a pool from which to draw. In fact it is most desirable to use persons experienced with the product being manufactured. In those companies making particularly complex or unusual products it is mandatory that selection of trainees be from those persons having a fundamental knowledge and understanding of the product, inasmuch as it is seldom possible to get personnel experienced in both the process and in quality control work. For example, a company may be engaged in the manufacture of a product that is dependent upon a very complex metallurgical or chemical procedure, and the statistical analysis of the characteristics of the finished product may, and very often does, reveal roots that extend back into the metallurgical or chemical processes. It can be easily understood, therefore, that it may be simpler to train some one in quality control work who already has a knowledge of the plant processes than to take some one experienced in quality control methods and attempt to train him in the many and complicated metallurgical and chemical processes.

Another point that should be mentioned is the fact that when a quality control program is being introduced the matter of costs always enters the picture. While top management may be opposed to the organization of an entirely new and separate department and the employment of outside help, with the consequent increase in the payroll, it may be willing to listen to a proposal of instituting a program which uses the personnel already available in the plant.

Once the decision has been made to select and train personnel already in the organization, it becomes necessary to scan the personnel records and try to find the type of person who would be most adaptable to training in the new statistical methods of controlling quality. It has been found that the best quality control operators are those that possess some or all of the following characteristics: (1) engineering judgment, (2) imagination, (3) diplomacy and tact, (4) patience, (5) honesty. In addition to the foregoing personal characteristics, a quality control technician should have included in his background: (1) knowledge of the process, (2) understanding of production problems, (3) knowledge of mathematics, (4) at least a high school education.

A study of personnel records will reveal that men combining most of the above mentioned qualifications are most likely to be found in the inspection department and in the engineering department. This does not exclude the possibility of finding trainees in other departments, but the most likely source will be in the departments mentioned. If the selected prospective quality control engineers are properly approached and their interests aroused in the advantages and future in quality control work, they will generally be willing to accept training. An incentive to offer is that the quality control department may be a step toward other supervisory and management positions.

The discussion thus far may be condensed into the following three very general considerations bearing on the selection of quality control personnel.

(1) Your own plant probably will provide the best source from which to draw qualified personnel.

(2) It may be easier to teach quality control to individuals experienced in your own particular processes than to teach your techniques to newly employed experienced quality control personnel.

(3) The engineering and inspection departments may be expected to contain persons who will be most likely to possess the qualifications necessary for quality control engineers and supervisors.

The problem next arises as to the method of training personnel in quality control work. Here, again, a great deal depends upon the size of the company and just how ambitious the quality control program is. There are a number of methods by which this problem may be met, such as:

(1) In-plant training of selected employees.

(2) University training.

(3) Training through community adult education programs.

(4) Training by consultants.

In a small firm it may be desirable to send one or two selected persons to a university for intensive training in statistical quality control. Fortunately quality control courses are offered in a number of universities as part of their regular curricula or as separate intensive ten-day courses. This training is most desirable. In addition to the universities, there are technical schools, vocational schools, and even high schools that are offering quality control courses aimed at providing persons with the fundamental concepts of the subject. A firm considering the installation of a quality control program cannot be urged too strongly to take advantage of this outside training.

Where a large corporation is getting a quality control program under way it is probably more advisable to institute a regular training program within the plant conducted by key personnel who have taken one of the courses mentioned above. This type of training has the advantage of focusing the quality control training on particular problems. In this way specialized training can be provided to fit directly into the original outline of the comprehensive program. It is, of course, necessary in training of this type to have some one who is qualified to assume the burden of the training program. Many firms have been very successful in selecting the men who are going to manage the program and in sending them to school for an intensive course of training, after which these men have conducted a regular in-plant training program.

This plan, however, will possess a serious weakness if the man who has been sent to school is not given sufficient time in which to try out the methods he has learned before he attempts to teach them to others: he will lack the practical experience so necessary to successful in-plant training. This weakness can be overcome and the training program speeded up in some cases by employing qualified consultants to conduct such classes. Many of these consultants have had a wide variety of practical experience and are considered experts in the quality control field. A combination of technical knowledge and practical experience is an essential requirement of the man who is to conduct a training program.

The above discussion of methods for training personnel may be summarized as follows.

(1) The entire personnel involved may be sent to a school for training.

(2) The key person in a quality control program may attend an intensive course and conduct an in-plant training class upon his return.

(3) An experienced quality control engineer may be employed to conduct the training and then supervise the program.

(4) A qualified consultant in quality control may be retained to organize and conduct an in-plant training course.

In broad outline a schedule of topics for an in-plant training course could be as follows.

(1) Statistical quality control — What it is and what it does.

(2) Demonstration of control chart principles — Measurement charts.

(3) Fraction defective and defects per unit charts.

(4) Acceptance sampling.

(5) Planning for statistical control.

(6) Review.

Most of the ideas expressed thus far have to do with the establishment of a quality control program in firms that have not had previous programs of this sort. This has been more or less deliberate because firms having well defined and successful programs in operation have already adopted a method of selecting and training personnel. This paper is aimed at those who want to get started in this work but who are not too sure just how to go about it.

One other point that should not be overlooked: a qualified statistician, or someone well versed in statistical methods, should be a part of any quality control program. There is a very good reason for this. Although a company may be entirely successful in installing a quality control program, there must be someone in the organization who is qualified to analyze data and to judge the results of savings or improvements that are effected. It is not enough to reduce rejections and scrap, or improve efficiency. Unless a competent analysis is made of the savings and improvements achieved, an embarrassing situation can arise when the question is raised as to just what the quality control program has accomplished either in actual savings in dollars and cents or improvement in quality. Unless top management can be shown

something concrete or substantial it is fairly certain that the effectiveness of the program may be greatly minimized.

The surest way for a quality control program to justify its existence as far as top management is concerned is to reduce costs. There may be those who will question this statement, citing cases where the cost of some product remained the same but the quality level was raised, or the quality control program actually resulted in more inspection, or some other argument. But the one fact that must remain uppermost in the mind of anyone engaged in quality control work is that it must result in a reduction of costs. Knowing this, it is of primary importance to give careful attention to the proper selection and the adequate training of the personnel to be engaged in quality control work.

Application of Statistical Methods to the Inspection of Porcelain Enamel

L. S. KAUFFMAN
AMERICAN STOVE COMPANY

[**Clinic 12**]

The experience which the American Stove Company had with the use of statistical methods in controlling quality during the war period showed that these techniques can be a valuable tool if wisely used. It is also the experience of this company that quality can best be maintained by a quality control department, independent of production, and charged with the responsibility of establishing and maintaining acceptance standards and inspection procedures. The company manufactures gas and coal ranges in three different plants. The inspection departments in these plants are responsible to the quality control department for adherence to quality standards and inspection procedures. These inspection procedures are being revised gradually to permit the use of control charts and more efficient sampling methods.

Since the process whereby a layer of porcelain enamel is applied to sheet iron represents an essential phase of range fabrication, it was considered a fertile field for the application of statistical methods. This paper will discuss the preliminary analysis leading to the establishment of control charts for the final inspection of finished white porcelain ware in the enamel shop. The data used were obtained at one of the plants in which the enamel shop was operating in the face of great difficulties at the time the data were collected. During the war the enamel shop in this plant was dismantled to provide additional space for production under a government contract. The plant resumed range production before the end of the war, and consequently it was necessary to relocate the spray booths, furnaces, and other enamel shop equipment in a portion of the factory not ideally suited to enameling. Because of this, the number of rejects was higher than would normally be expected.

Even under ideal conditions, there are many variables in the enameling process. The quality of the product is affected by the grinding and mixing of the ingredients, and the application and fusing of the enamel to the sheet metal. The characteristics of the iron from which the part is fabricated, and the forming of the part itself, also influence the finish of the porcelain product. In order to achieve efficiency and an even flow of production on the range assembly line it is essential that strict control of these variables be maintained in the enameling shop. Statistical methods are believed to be the best means of achieving such control.

It has been, and will continue to be, the practice to conduct a 100% inspection of the finished white ware before it leaves the enamel shop. It is more economical to remove rejects at this station than to do so on the range assembly line. At the time the finished white ware leaves the furnace it is removed from the furnace chain and placed on a moving inspection belt. As the pieces pass the inspection station they are inspected visually for 27 possible types of defects. The pieces are classified in four groups with reference to their position on the range regardless of the range model number on which they are to be used. These groups are: body sides, door panels, top frames, and mantel backs. There are, in addition, smaller enamel parts which are inspected but not tallied at the inspection station. Reworked ware is also carried on the belt and inspected for defects. This ware is tallied on separate sheets. Since the percentage of rejects is higher on reworked ware, it must be recorded separately from first run ware in order to obtain a true picture of the enameling process.

A tally sheet is used for each of the four different groups of ware: body sides, door panels, top frames, and mantel backs. Such defects as under or over fire, heavy or light spray, fish scale, copper heads, blisters, hairlines, dirt and specks, handling, lumps, sagging, scumming, spray tear, pits, chipped, reboil, fabricating, and bad iron are among the 27 defects included on each sheet.

Approximately 2,000 pieces of finished white enamel ware of various sizes pass the inspection station every eight hours.

The first step taken in this investigation was to compile data on past performance. The data were broken down into two periods: that from May to the end of September, 1945, and from September through the end of the year. Production was increased in September, and at the same time a different type of enamel was introduced. Among other things, it was desired to know

if this change had any appreciable effect on the quality of the work. For both periods it was found that seven types of defects accounted for approximately 75% of the total rejects. If these seven types of defects could be brought into statistical control, then the other twenty types could be disregarded for all practical purposes as long as they continued to retain their relative insignificance. The seven major defects are: dirt and specks, handling, light spray, lumps, spray tear, pits, and blisters.

Table 1 and Table 2 present the essential data for the seven major defects and for the total defects for the two periods. In these tables the $\bar{n}$ values in column 1 represent the average number of pieces inspected daily for the days listed in column 3. Column 2 shows the total days in production for each period. In order to arrive at an estimate of the $\bar{p}$ values that might be expected with the process under statistical control, those days were omitted on which the sample size or the percentage of defects were clearly not representative of the process, thus leading to the data in column 3. The $\bar{p}$ values in column 4 are the average reject percentages for the average number of pieces inspected for the number of days shown in column 3. Columns 5-6-7 are self explanatory.

In reviewing these data it should be remembered that the inspection is purely visual, and that inspectors' errors of judgment affect the final results. The average percentage of rejects of body sides and door panels was approximately equal for the two periods, whereas there was an appreciable difference in these percentages for top frames and mantel backs. When the totals at the top of the table are compared with the breakdowns for the seven types of defects, it is seen that the seven types were in control for more days that were the totals. The rejections due to pits and blisters were higher during the second period, which may possibly have been caused by the use of a different enamel during the latter period. The difference between the $\bar{p}$ values for the different groups for each type of defect can be logically explained as due to the shape or size of the pieces.

Table 1: INSPECTION OF FINISHED WHITE PORCELAIN WARE
MAY 12, 1945 TO SEPTEMBER 24, 1945

		1 $\bar{n}$	2 Total Days	3 Net Days for $\bar{p}$	4 $\bar{p}$ %	5 UCL %	6 LCL %	7 Days Out of Control
Total Rejects	Body Sides	428	83	73	15.2	20.4	10.0	42
	Door Panels	686	89	88	10.6	14.1	7.1	37
	Mantle Backs	236	75	67	17.0	24.3	9.7	21
	Top Frames	211	80	75	22.8	32.0	13.6	28
Dirt and Specks	Body Sides	428	83	79	3.6	6.3	0.9	25
	Door Panels	686	89	89	2.6	4.4	0.8	10
	Mantle Backs	236	75	68	5.0	9.3	0.8	12
	Top Frames	211	80	74	5.1	9.6	0.6	7
Handling	Body Sides	428	83	76	2.1	4.2	0.0	21
	Door Panels	686	89	89	2.8	4.7	0.9	21
	Mantle Backs	236	75	70	4.2	8.1	0.3	10
	Top Frames	211	80	76	4.5	8.7	0.2	9
Light Spray	Body Sides	428	83	81	1.0	2.5	0.0	6
	Door Panels	686	89	83	0.8	1.8	0.0	13
	Mantle Backs	236	75	67	0.9	2.7	0.0	15
	Top Frames	211	80	68	2.0	4.9	0.0	19
Lumps	Body Sides	423	83	78	1.6	3.1	0.0	12
	Door Panels	686	89	88	1.2	2.4	0.0	9
	Mantle Backs	236	75	70	1.4	3.7	0.0	7
	Top Frames	211	80	74	2.0	4.9	0.0	6
Spray Tear	Body Sides	428	83	78	0.9	2.2	0.0	13
	Door Panels	686	89	86	0.6	1.4	0.0	8
	Mantle Backs	236	75	71	0.8	2.0	0.0	15
	Top Frames	211	80	77	3.1	6.6	0.0	10
Pits	Body Sides	428	83	79	0.9	2.3	0.0	11
	Door Panels	686	89	87	0.4	1.1	0.0	9
	Mantle Backs	236	75	71	0.5	1.8	0.0	6
	Top Frames	211	80	80	1.1	3.2	0.0	5
Blisters	Body Sides	428	83	78	0.5	1.4	0.0	11
	Door Panels	686	89	86	0.2	0.7	0.0	11
	Mantle Backs	236	75	70	0.5	1.9	0.0	12
	Top Frames	211	80	76	0.4	1.6	0.0	6

The data shown in Tables 1 and 2 were compiled to arrive at an estimate of fraction defective values which would be sufficiently characteristic of the process to be adopted as tentative standards. This is the main reason that these data were compiled over such a long period rather than for only a few weeks. The $\bar{p}$ values shown in these tables were therefore adopted as tentative standard values, p'.

At this point, it was decided to adopt standard sample sizes also, and to use control charts for number of defectives rather than fraction defective. A standard sample size of 200 was adopted for spray tear and 100 for the other six principal types of defect. It was thus possible to construct a table of tentative standards for control charts, and to make up blank control chart grids with standard center and control lines drawn in. One chart form was made up for each of the four groups of enamel ware with a grid for total rejects in that group shown at the top of the form followed by grids for each of the seven major types of defects in that group. These chart forms were 16" x 22" in size, and were posted for use at the inspection station.

Tally sheets on which the inspectors record their data provide columns labelled in units of 100, so that after each hundredth piece has passed an inspector's station that sample is completed and he begins tallying rejects in the adjacent column. All 27 defects are recorded on these tally sheets, but only totals and the seven major defects per hundred pieces inspected are posted on the control charts. Of course, if any of the other twenty defects increase appreciably in magnitude at any time, additional control charts will be added for the particular defects causing trouble.

At the time this paper was prepared, these charts had been in operation a little less than two months. By checking back on points outside control limits, some improvement has been made, but the process has not at this writing attained a satisfactory state of statistical control. When a new plant addition now under construction is completed, it is confidently expected that the procedures now in effect will lead to eventual control with a set of standards substantially better than those currently in force.

It should be emphasized that these charts do not eliminate 100% inspection. Therefore, they do not reduce the cost of inspection. They are of material assistance in the following ways:

1. They help to improve the quality of inspection.
2. They help to improve the quality of the product.
3. They will eventually make it possible to bring the process under statistical control.
4. They provide production foremen and supervisors with reliable information concerning the state of the process.
5. They are helping to reduce the number of rejects, and thereby to reduce the cost of production.

Table 2: INSPECTION OF FINISHED WHITE PORCELAIN WARE
SEPTEMBER 24, 1945 TO DECEMBER 31, 1945

		1 $\bar{n}$	2 Total Days	3 Net Days for $\bar{p}$	4 $\bar{p}$ %	5 UCL %	6 LCL %	7 Days Out of Control
Total Rejects	Body Sides	507	45	26	17.2	22.2	12.2	30
	Door Panels	1351	59	54	11.6	14.2	9.0	34
	Manlte Backs	443	51	16	22.6	28.5	16.7	39
	Top Frames	337	58	43	27.9	35.2	20.6	34
Dirt and Specks	Body Sides	507	45	37	4.19	6.86	1.52	27
	Door Panels	1351	59	55	2.11	3.25	0.97	29
	Mantle Packs	443	51	47	2.83	5.17	0.49	25
	Top Frames	337	58	53	3.08	5.90	0.16	12
Handling	Body Sides	507	45	39	2.08	3.97	0.19	8
	Door Panels	1351	59	59	1.93	3.04	0.82	14
	Mantle Backs	443	51	50	3.28	5.80	0.76	13
	Top Frames	337	58	55	4.17	7.44	0.90	10
Light Spray	Body Sides	507	45	34	0.55	1.57	0.00	15
	Door Panels	1351	59	59	0.71	1.43	0.00	7
	Mantle Backs	443	51	37	0.86	2.18	0.00	19
	Top Frames	337	58	37	3.69	6.78	0.60	26
Lumps	Body Sides	507	45	30	1.92	3.72	0.12	18
	Door Panels	1351	59	52	1.83	2.91	0.75	16
	Mantle Backs	443	51	28	2.84	5.18	0.50	21
	Top Frames	337	58	57	1.86	4.02	0.00	4
Spray Tear	Body Sides	507	45	44	0.23	0.80	0.00	5
	Door Panels	1351	59	58	0.13	0.19	0.00	10
	Mantle Backs	443	51	51	0.20	0.83	0.00	3
	Top Frames	337	58	45	0.79	2.23	0.00	18
Pits	Body Sides	507	45	14	1.555	4.30	0.00	22
	Door Panels	1351	59	41	1.09	1.93	0.25	24
	Mantle Backs	443	51	14	0.81	2.07	0.00	39
	Top Frames	337	58	47	1.86	4.08	0.00	14
Blisters	Body Sides	507	45	32	1.36	2.92	0.00	13
	Door Panels	1351	59	27	1.03	1.84	0.22	33
	Mantle Backs	443	51	7	1.30	2.89	0.0	43
	Top Frames	337	58	50	1.52	3.50	0.0	11

The Use of Statistics in the Design of Experiments

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[**Clinic 7**]

People are usually surprised when they learn for the first time that there is such a thing as a scientific approach to experimental design; they are still more surprised to find that the design of experiments in such diverse fields as nutrition, aerodynamics, and psychology falls properly within the province of the statistician. Yet the reasonableness of this latter point, at least, should be clear enough. Experiments are undertaken for the purpose of getting numerical data — counts or measurements. From these data scientific conclusions are to be drawn, and the drawing of these conclusions is a matter of statistical inference. What more natural than that the statistician, who must eventually try to make sense of the results, should have a voice in designing the investigation from which the results are to come?

Much less obvious is the fact that the design of experiments is a specialized professional field which calls for considerable resources in ingenuity and technical knowledge. In order to understand why this is true, let us look briefly at the purpose of all experimentation to see if we can deduce a set of standards which a good experiment ought to satisfy.

The general standards are clear enough. Qualitatively, the experi-

ment should be capable of shedding light upon the question under investigation. Quantitatively, it should be such that there exists at least one possible outcome which, if it happens, will enable an inference to be made. The inference need not be conclusive in the sense that it answers the question with finality; it need only be an item of evidence which will be added to other evidence, the eventual decision being guided ultimately by the entire mass. All this is obvious, and it may still be far from clear that such elementary points need discussion.

Consider the qualitative requirement first: That the experiment be capable of shedding light upon the question under investigation. Millions of dollars have been wasted in defective experiments which neglected this rule; millions more by people who drew conclusions from such experiments, and acted upon them. A well-known example is the pre-election poll of the Literary Digest in 1936. Ballots were sent to lists of registered voters, telephone subscribers, and other more or less selected groups. As it turned out, these people simply did not represent the mass of citizens who went to the polls in the following November. The error was, of course, in sampling. The Gallup poll of the same year, using better sampling methods and a comparatively small number of ballots, predicted the outcome of the election quite accurately. We may call this type of mistake the "guinea pig fallacy," since it used to be made frequently by biologists who studied guinea pigs and then drew conclusions about human beings. When an inspector opens one box of a shipment of (say) fifty and accepts or rejects the lot on the basis of this box, he needs assurance that statistical control exists—that is, that the box chosen for inspection is "representative;" otherwise he falls into the guinea pig fallacy.

A second type of error, less frequently made now than formerly, but still to be guarded against, is found in the "uncontrolled" experiment. Suppose a health officer is investigating a typhoid epidemic, and checking the local milk supply. He asks each family with typhoid, "Where do you get your milk?" and makes the following table:

Customers of	No. of Typhoid Cases
Dairy A	64
Dairy B	19
Dairy C	4
Other Dairies	4

As they stand, these data are incapable of shedding light upon the question of whether or not typhoid has come from infected milk. True, two-thirds of the typhoid cases used milk from Dairy A. The beginner in experimentation might think badly of Dairy A's product. But suppose further investigation shows that nine out of every ten households in the community get their milk from Dairy A. Going by averages alone, and assuming the milk has nothing to do with typhoid, Dairy A is entitled to 82 typhoid cases out of the total of 91. The actual number observed (64) is small enough to suggest the possibility that using Dairy A's milk actually gave some protection against typhoid. The mistake frequently made in this type of experiment is to leave out the families that **did not** get typhoid; that is, to omit the "control."

Even when an experiment is qualitatively capable of providing information, it may be on so limited a scale that no inference can be made, no matter what the outcome may be. Suppose the claim is made that it is possible to predict the outcome of some chance event—say the tossing of a coin. "Heads" are predicted, the coin is tossed, and heads actually does come up. Here is an experiment which does not of itself prove anything, and does not even raise much of a presumption; it is too easy to guess the outcome, and in fact a random guess will be right fifty per cent of the time. But if five such successful predictions are made, without one failure, the performance has a more convincing quality, since the chance of guessing right five consecutive times is one in thirty-two.

Perhaps acceptance inspection is the most obvious illustration in industrial work where the scope of the experiment is inadequate. Assume some definition for "good lots" and "bad lots;" the inspection plan presumably should accept good lots and reject bad ones with a misjudgment only once in a while. The size of the sample must be capable of giving the desired amount of discrimination. If for example a "good lot" is defined as one per cent defective and a "bad lot" as three per cent defective, a sample size of 500 will be needed to discriminate between them with 95 per cent confidence (assuming a large lot size). If fewer specimens are inspected, more bad lots will be accepted and/or more good ones rejected.

A fallacy that is still deeply rooted in scientific experimentation is that of requiring "uniform conditions," with all factors "held constant" except one. Actually, uniform conditions are a myth. It is certainly desirable to achieve a reasonable approach to uniformity, but just how far to go is a matter of judgment to be decided for each case; no general rule can be laid down. Sometimes so much uniformity can be imposed upon an experiment that its purpose is defeated. The results then relate to a highly artificial environment quite different from reality, and there follows the deflating experience of experimental predictions that do not work out in practice.

It is sometimes most inadvisable to try to hold all factors but one constant, since frequently there is an interaction between factors that is more important than any of the direct effects. Suppose a chemical laboratory desires to test the relative accuracy of two balances. The classical pattern may be followed, and a reliable technician secured to make a number of weighings of the same article on each of the two balances. If instead, it is desired to investigate the differences between two technicians, then each may make a series of weighings

on the same balance. But according to the modern theory of experimentation, these two investigations would be combined in a single experiment, in which each technician would use each balance. If the technicians are designated by T_1 and T_2, and the balances by B_1 and B_2, the resulting experiment makes possible three comparisons as follows (T_1B_2 means the results obtained when Technician No. 1 used Balance No. 2, and so on):

Comparison 1: T_1B_1 and T_1B_2 against T_2B_1 and T_2B_2
Comparison 2: T_1B_1 and T_2B_1 against T_1B_2 and T_2B_2
Comparison 3: T_1B_1 and T_2B_2 against T_2B_1 and T_1B_2.

In Comparison 1, the balances are equalized on both sides, and any difference in excess of random error must be due to technicians.

In Comparison 2, technicians are equalized on both sides, and any difference must be due to balances.

In Comparison 3, both balances and technicians are equalized. If there is a difference, it must be due to some circumstance that makes the individual balances unequally suited to the individual technicians. For example, if one technician is left-handed and the other right-handed, there might be a difference between the balances leading T_1 to prefer one balance and T_2 the other. Such an effect is called an interaction. It happens whenever the effect produced by one factor is modified by changes in the other. Interaction effects are generally overlooked by the classical one-factor method of experimentation.

The leading work on modern experimental design is, **The Design of Experiments** by R. A. Fisher (3rd edition, 1942; Oliver & Boyd, Edinburgh). A fairly elaborate treatment from the engineering point of view can be found in **Industrial Statistics** by H. A. Freeman (Wiley, 1942); a brief introduction, also for engineers, is given in the present writer's **Industrial Statistics and Quality Control** (2nd edition, 1946; Edwards & Broughton, Raleigh, North Carolina). The subject is worth careful study, since it opens opportunities for extending our knowledge, at the same time making efficient use of our experimental resources beyond anything possible with the classical methods.

RECORD OF CLINIC PAPERS

NOT Published In Industrial Quality Control

Following is a listing of the clinic papers given at the conference but not published with the other conference papers in **Industrial Quality Control.**

Clinic No. 2.

"An Application of p Charts"—Keith E. Ross, Product Quality Division, General Electric Company, Fort Wayne, Indiana.
Reason: No manuscript available.

Clinic No. 4.

"Some Quality Control Methods for Short Runs and Job Lots"—Ralph E. Wareham, Manager, New Products, National Photocolor Corp., New York, N. Y.

Clinic No. 5.

"Practical Application of Quality Control at the John Deere Tractor Company"—E. L. Fay, Chief Inspector, John Deere Tractor Company, Waterloo, Iowa.

Reason: Substantially this same paper appeared as **Quality Control Report** No. 8, September, 1945. These reports are available at a price through the Department of Commerce, Office of Technical Services, Washington 25, D. C.

Clinic No. 8.

"How Quality Control is Introduced to Top Management"—Frederick J. Halton, Jr., Assistant to the President, Deere and Company, Chicago, Illinois.

Reason: This paper was summarized adequately on page 25 of the May issue and on page 11 of the January Management issue of **Industrial Quality Control.**

Clinic No. 13.

"Quality Control Applied to the Mass Production of Precision Ball and Roller Bearings"—C. R. Scott, General Supervisor of Quality, SKF Industries, Inc., Philadelphia, Pa.

Reason: This paper was published in the November 1945 issue of **Industrial Quality Control.**

Clinic No. 14.

"Special Techniques in p-Charting"—Herbert J. Sprengel, Quality Control Engineer, General Electric X-Ray Corp., Chicago, Ill.
Reason: No manuscript available.

Clinic No. 15.

"Quality Control in Processes Involving the Human Element Exclusively"—James M. Ballowe, Manager, Quality Inspection Department, Aldens, Chicago, Ill.

Reason: Substantially this same paper appeared as **Quality Control Report** No. 7, September 1945. Available as mentioned for Clinic No. 5 above.

Clinic No. 19.

"Statistical Quality Control in Radio Manufacture"—Fred Trowbridge, Quality Control Engineer, Sentinel Radio Corp., Evanston, Ill.
Reason: Substantially this same paper appeared as **Quality Control Report** No. 5, September 1945. Available as mentioned for Clinic No. 5 above.

NOTICE

The publication of the Reports of the Midwest Quality Control Conference is completed in this issue. The Reports appear in the May, July, September, and November issues of the magazine and are available at a cost of $4.00 for the set or $1.00 each for individual copies. Orders should be sent to Martin A. Brumbaugh, Crosby Hall, University of Buffalo, Buffalo 14, New York. Remittance with orders will be appreciated.

. . . Review . . .

A BIBLIOGRAPHY OF STATISTICAL QUALITY CONTROL. Grant I. Butterbaugh. Univ. of Washington Press, October 1946. Pp. 114. $1.50. Review by Doris Newman, Instructor in Statistics, University of Buffalo.

Dr. Butterbaugh, in his annotated bibliography, has listed and commented on 712 articles, manuals and books, which appeared during the period 1924-1945, dealing with statistical quality control. The value of such a bibliography in a comparatively new field is apparent.

The booklet is divided into three parts and includes an index of authors. Part I contains references which appeared in periodical literature. The periodicals are listed alphabetically and under each periodical the articles are arranged consecutively according to date of appearance. The following is an entry, selected at random which appears in Part I:

A71 AMERICAN STATISTICAL ASSOCIATION, JOURNAL (Mar., 1941) 36:53-60 On the initiation of statistical method for quality control in industry. L. E. Simon.

Practical steps are outlined which may help to "sell" statistical methods to management of industry. Necessity of devising simple procedures which may be applied by persons other than the statistician if there is to be an immediate use of statistical methods for quality control on a large scale. See **Management Review** (September, 1941) 30:-335-336, for abstract of above article.

Part II contains an alphabetical list of manuals, monographs and pamphlets by publishing agency.

A typical entry in Part II is:

a9 AMERICAN STANDARDS ASSOCIATION, New York, N. Y. Control Chart Method of Controlling Quality During Production (April, 1942). Pp. 41.

A manual on the use of control charts known as Z1.3-1942 which has become a handbook for all who are interested in the subject of quality control by statistical methods. See reviews: **Industrial Standardization** (May, 1942) 13:109-110, by John Gaillard; **American Statistical Association, Journal** (September, 1945) 40.379-380, by Frederick Mosteller.

Part III lists books on quality control according to author. The following was selected at random to illustrate:

b7 Juran, J.M.

Management of Inspection and Quality Control, Harper and Bros., New York, N. Y., 1945. Pp. 233.

A manual for engineers, plant managers, plant supervisors, and inspection personnel which sets forth the techniques and procedures, as well as the basic principles of quality control. See reviews: **Mechanical Engineering** (June, 1945) 67:-417; **Industrial Quality Control** (July, 1945) 2, No. 1: 18-19 by M. A. Brumbaugh; **American Statistical Association, Journal** (September, 1945) 40:395-396 by A. I. Peterson.

A comparison between this work and other bibliographies on statistical quality control, namely, QUALITY CONTROL REPORT No. 11 of the Office of Production Research and Development, War Production Board, September, 1945 and the bibliography which appeared in INDUSTRIAL QUALITY CONTROL, Vol. 1 Nos. 1-6, July 1944- May 1945 reveals several omissions. However, this reviewer did not notice omission of any important reference. The absence of a subject index will seriously curtail the value to students and to those, with a limited background in statistical quality control, who are seeking assistance for practical applications. Its greatest value will undoubtedly be to those who have been following the literature as it appeared, and are familiar with the type of contribution each author has made. For this group, the bibliography will be a handy reference—a short cut in research.

A Sampling Procedure for Design Tests of Electron Tubes*

(Sponsored by Joint Electron Tube Engineering Council)

By S. W. Horrocks, P. M. Dickerson, H. F. Dodge, E. R. Ott, H. G. Romig (alternate member), W. B. Rupp, J. R. Steen, R. E. Wareham, A. K. Wright (JETEC Committee on Sampling Procedure, May, 1945).

The Committee on Sampling Procedure was established on July 21, 1943 as part of the Electron Tube Section of the Radio Manufacturers Association (RMA). The purpose of the Committee is to develop sampling methods and to act in an advisory capacity towards standardization of Sampling Procedures throughout the Electron Tube industry. This Committee was later embodied as a main Committee of the Joint Electron Tube Engineering Council of the RMA and NEMA. This Council was established in 1945 to handle all engineering matters for the Electron Tube industry for both trade associations, Radio Manufacturers Association and National Electrical Manufacturers Association.

One of the earliest projects handled by the Committee was the development of a statistically sound sampling inspection procedure for so-called "design tests" of electron tubes. In general, design tests relate to characteristics that are normally quite stable and are relatively less important to the consumer. The nature of these tests is such that only relatively small samples are practicable. The Joint Army-Navy Specification JAN-1A incorporated a sampling plan for design tests allowing (1) not more than 10% of the sample tubes to contain design test defects of any one kind and (2) not more than 20% of the sample tubes to contain design test defects of any kind. Because of the extremely wide range in lot sizes for different classes of electron tubes, such a simplified sampling plan was in effect too strict for small lot sizes and too liberal for large lot sizes. Moreover, no distinction was made in the relative seriousness of different kinds of design test defects. The Committee accordingly set about to prepare a sampling inspection plan that would be relatively free of these faults. The new procedure covers all aspects of the acceptance problem and provides an operationally definite criterion for reducing inspection for a product whose quality is regularly well controlled within the intent of the specification.

The procedure developed by the Committee was approved by J.E.T.E.C. (Joint Electron Tube Engineering Council), was approved by the JAN Committee in September 1945, and is reproduced in full below. It will be noted that the procedure provides for two Acceptable Quality Levels (AQL), namely 6% defective and 3% defective for individual design test characteristics. Each design test of a particular type of electron tube is classified as either a Standard Design Test with an AQL — 6% or a Special Design Test with an AQL — 3%. For any design test, if product submitted for inspection has quality equal to the AQL, the chances of acceptance are of the order of 94 to 98 out of 100. If quality runs consistently better than the AQL, reduced inspection is permitted, thus serving as an incentive for the manufacturer to strive for better quality. The operating characteristics of the sampling plans involved are appended to this article and show the degree to which the plans will discriminate for various levels for submitted quality.

*"Editor's Note: The JETEC Committee on Sampling Procedure has been active also on other phases of sampling procedures and related quality controls as applied to electron tube manufacture. The Committee prepared a new Acceptance Sampling Procedure for Production Tests After the Holding Period. It is normal procedure in the manufacture of electron tubes to hold the product a few days before final clearance as a check against slow leaks and similar faults. At the end of this holding period the product is then tested for important characteristics called Production Tests. The sampling procedure developed by the Committee is based on an Acceptable Quality Level (AQL) of 1% and provides a Double Sampling plan with Normal Testing, Stricter Testing, and Reduced Testing. The eligibility for or the loss of eligibility from these various levels of testing severity are determined by the process average of the preceding lots.

This Sampling Procedure was included in the Inspection Manual issued by the Joint Army-Navy Electron Tube Committee. The JETEC Committee is currently developing a Life Tube Sampling and Testing Procedure to judge electron tube life.

DESIGN TEST SAMPLING PROCEDURE: STANDARD DESIGN TESTS

1. Standard Design Tests are those identified by a single asterisk (*) on the tube specification sheets, and shall be made on a sample from each quantity of tubes of any one type submitted for Standard Design Test acceptance at any one time (hereinafter called the Lot). The tube specification limits shall govern the acceptability of each tube in the sample for those tests. When a limit specified for a Standard Design Test is exceeded, the result is called a Standard Design Test "defect."

The acceptance of the Lot shall be governed by conformance criteria as described in the following Double Sampling Plans applied to each separate Standard Design Test. All samples shall be selected at random from the Lot in such a manner as to be representative of the Lot and as approved by the Inspector.

The Normal Testing Plan for Standard Design Tests, (Table I) shall apply except that the Reduced Testing Plan (Table II) may be used if eligibility for Reduced Testing is established. Loss of eligibility requires a return to the Normal Testing Plan. (See Eligibility Criteria below)

Conformance Criteria for Table I:

The Lot shall be considered as conforming for an individual Test, if the number of defects (d_1) observed for that Test in the first sample (n_1) does not exceed the acceptance number for the first sample (c_1). When d_1 exceeds c_1 but not the acceptance number for combined sample (c_2), results of testing a second sample (n_2) for the Test in question shall be combined with the results of n_1. If the total number of defects ($d_1 + d_2$) observed in the combined sample ($n_1 + n_2$) does not exceed c_2, the Lot shall be considered as conforming for that Test.

When for an individual Test, either d_1 or $d_1 + d_2$ exceeds c_2, the Lot is nonconforming for that Test. Such nonconformance shall be cause for rejection of the Lot, or at the option of the manufacturer, for testing all tubes remaining in the Lot for that particular Standard Design Test.

Eligibility Criteria for Reduced Testing

Reduced Testing may be used for any Standard Design Test if, in accumulated Normal Testing results of first samples only from the last ten (10) successive Lots (irrespective of time interval between lots), the computed percent defective for that Test does not exceed three percent (3.0%); the computed percent defective is the ratio, expressed in percent to the nearest tenth of one percent, of the number of defects (d_1) for that Test in these first samples to the total number of tubes in these first samples. When these accumulated results represent less than seventy (70) tubes, results of additional first samples from immediately preceding Lots may be included at option of the manufacturer, to obtain seventy (70) tubes or the next nearest multiple of the first sample size over seventy (70).

Reduced Testing may continue for a Standard Design Test unless nonconformance of a Lot, as described below, occurs for that test. When such nonconformance occurs, Reduced Testing may be continued provided the computed percent defective (as defined in preceding paragraph) for that Test from the first samples of the last ten (10) successive Lots, including the current nonconforming lot, does not exceed six percent (6.0%). Otherwise, loss of eligibility occurs and Normal Testing shall be resumed for that Test until eligibility to use Reduced Testing is reestablished.

In the cumulations referred to in the preceding paagraphs, test results representing an instance of highly defective quality, due to a known irregularity in manufacturing or testing that has been isolated and corrected, may be excluded.

TABLE I: STANDARD DESIGN TEST—NORMAL TESTING PLAN

Lot Size, N — No. of Tubes	Sample Sizes: Exact Number of Tubes Tested as a Sample — First Sample Size, n_1	Second Sample Size, n_2	Combined Sample Size, $n_1 + n_2$	Acceptance Number: Individual Test Defects — In First Sample, c_1	In Combined Sample, c_2
6-50	5	5	10	0	1
51-100	7	14	21	0	2
101-200	8	16	24	0	3
201-500)	10	20	30	0	4
201-500) Note a	15	15	30	1	4
501-1000	15	25	40	1	5
1001-2000	16	30	46	1	6
2001-5000	18	35	53	1	7
5001-10,000	20	45	65	1	8
Over 10,000	25	50	75	1	9

Note a: This Lot size usually represents the breaking point between low and high production levels. Either plan may be used at the option of the manufacturer since each provides the same quality protection, the principal difference being the probability of second sampling.

Note b: For any lot size, the manufacturer may use sample sizes and criteria specified for any larger lot size to simplify operational and clerical administration.

TABLE II: STANDARD DESIGN TEST—REDUCED TESTING PLAN

Lot Size, N — No. of Tubes	Sample Sizes: Exact Number of Tubes Tested as a Sample — First Sample Size, n_1	Second Sample Size, n_2	Combined Sample Size, $n_1 + n_2$	Acceptance Number: Individual Test Defects — In First Sample, c_1	In Combined Sample, c_2
51-200	5	5	10	0	1
201-10,000	7	14	21	0	2
Over 10,000	8	16	24	0	3

Note: The Reduced Testing Plan does not apply to Lot Sizes of 50 or less; use Normal Testing. Table I).

Conformance Criteria for Table II

For any individual Standard Design Test on Reduced Testing the procedure shall follow the same rules as for Normal Testing except that the Sample Sizes and Acceptance Numbers of Table II shall apply.

Under conditions where some individual Tests are on Reduced Testing and others are on Normal Testing, the tubes to be used for the Reduced Testing sample shall be identified prior to test.

DESIGN TEST SAMPLING PROCEDURE: SPECIAL DESIGN TESTS

2. Special Design Tests are those identified by a (symbol to be supplied) on the tube specification sheets, and shall be made on a sample from each quantity of tubes of any one type submitted for Special Design Test acceptance at any one time (hereinafter called the Lot). The tube specification limits shall govern the acceptability of each tube in the sample for those tests. When a limit specified for a Special Design Test is exceeded, the result is called a Special Design Test "defect."

The acceptance of the Lot shall be governed by conformance criteria as described in the following Double Sampling Plans applied to each separate Special Design Test. All samples shall be selected at random from the Lot in such manner as to be representative of the Lot and as approved by the Inspector.

The Normal Testing Plan for Special Design Tests (Table III) shall apply except that the Reduced Testing Plan (Table IV) may be used if eligibility for Reduced Testing is established. Loss of eligibility requires a return to the Normal Testing Plan. (See Eligibility Criteria below)

Conformance Criteria for Table III

The Lot shall be considered as conforming for an individual Test, if the number of defects (d_1) observed for that Test in the first sample (n_1) does not exceed the acceptance number for the first sample (c_1). When d_1 exceeds c_1 but not the acceptance number for combined sample (c_2), results of testing a second sample (n_2) for the Test in question shall be combined with the results of n_1. If the total number of defects ($d_1 + d_2$) observed in the combined sample ($n_1 + n_2$) does not exceed c_2, the Lot shall be considered as conforming for that test.

When for an individual Test, either d_1 or $d_1 + d_2$ exceeds c_2, the Lot is non-conforming for that Test. Such nonconformance shall be cause for rejection of the Lot, or at the option of the manufacturer, for testing all tubes remaining in the Lot for that particular Special Design Test.

Eligibility Criteria for Reduced Testing

Reduced Testing may be used for any Special Design Test if, in accumulated Normal Testing results of first samples only from the last ten (10) successive Lots (irrespective of time interval between Lots), the computed percent defective for that Test does not exceed one and one-half percent (1.5%); the computed percent defective is the ratio, expressed in percent to the nearest tenth of one percent, of the number of defects (d_1) for that Test in these first samples to the total number of tubes in these first samples. When these accumulated results represent less than seventy (70) tubes, results of additional first samples from immediately preceding Lots may be included at option of the manufacturer, to obtain seventy (70) tubes or the next nearest multiple of the first sample size over seventy (70).

Reduced Testing may continue for a Special Design Test unless nonconformance of a Lot, as described below, occurs for that test. When such nonconformance occurs, Reduced Testing may be continued provided the computed percent defective (as defined in preceding paragraph) for that Test from the first samples of the last ten (10) successive Lots, including the current nonconforming Lot, does not exceed three percent (3.0%). Otherwise, loss of eligibility occurs and Normal Testing shall be resumed for that Test until eligibility to use Reduced Testing is established.

In the cumulations referred to in the preceding paragraphs, test results representing an instance of highly defective quality, due to a known irregularity in manufacturing or testing that has been isolated and corrected, may be excluded.

TABLE III: SPECIAL DESIGN TEST—NORMAL TESTING PLAN

Lot Size, N — No. of Tubes	Sample Sizes: Exact Number of Tubes Tested as a Sample — First Sample Size, n_1	Second Sample Size, n_2	Combined Sample Size, $n_1 + n_2$	Acceptance Number: Individual Test Defects — In First Sample, c_1	In Combined Sample, c_2
6-50	5	10	15	0	1
51-100	7	14	21	0	1
101-200	8	16	24	0	2
201-500)	10	20	30	0	2
201-500) Note a	15	15	30	1	2
501-1000	15	25	40	1	3
1001-2000	16	30	46	1	3
2001-5000	18	35	53	1	4
5001-10,000	20	45	65	1	4
Over 10,000	25	50	75	1	5

Note a: This Lot size usually represents the breaking point between low and high production levels. Either plan may be used at the option of the manufacturer since each provides the same quality protection, the principal difference being the probability of second sampling.

Note b: For any lot size, the manufacturer may use sample sizes and criteria specified for any larger lot size to simplify operational and clerical administration.

TABLE IV: SPECIAL DESIGN TEST—REDUCED TESTING PLAN

Lot Size, N — No. of Tubes	Sample Sizes: Exact Number of Tubes Tested as a Sample — First Sample Size, n_1	Second Sample Size, n_2	Combined Sample Size, $n_1 + n_2$	Acceptance Number: Individual Test Defects — In First Sample, c_1	In Combined Sample, c_2
51-200	5	10	15	0	1
201-10,000	7	14	21	0	1
Over 10,000	8	16	24	0	2

Note: The Reduced Testing Plan does not apply to Lot Sizes of 50 or less; use Normal Testing. (Table III).

Conformance Criteria for Table IV

For any individual Special Design Test on Reduced Testing the procedure shall follow the same rules as for Normal Testing except that the Sample Sizes and Acceptance Numbers of Table IV shall apply.

Under conditions where some Individual Tests are on Reduced Testing and others are on Normal Testing, the tubes to be used for the Reduced Testing sample shall be identified prior to test.

APPENDIX

The following charts show the operating characteristics, i.e. probability of acceptance curves, for the various sampling plans involved in the over-all sampling procedure. On the charts are shown two additional curves, one indicating the Average Outgoing Quality (AOQ) and the other the probability of taking a second sample as a function of the value of Fraction Defective in Submitted Product (p). These charts will be found useful in the evaluation of the over-all sampling procedure.

CHART 1 April 28, 1948

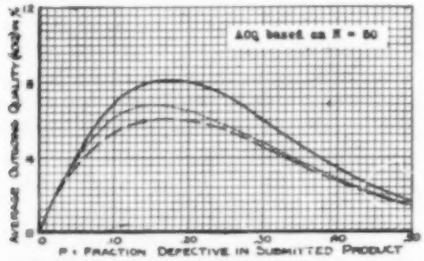
NORMAL TESTING: LOT SIZE, N = 8-50

AQL = 6%: $n_1 = 5$, $n_2 = 5$; $c_1 = 0$, $c_2 = 1$ } c_2 applies to $n_1 + n_2$

AQL = 3%: $n_1 = 5$, $n_2 = 10$; $c_1 = 0$, $c_2 = 1$ } c_2 applies to $n_1 + n_2$

JAN: $n = 5$, $c = 0$

CODE: —— AQL = 6% ····· AQL = 3% — — JAN Plan



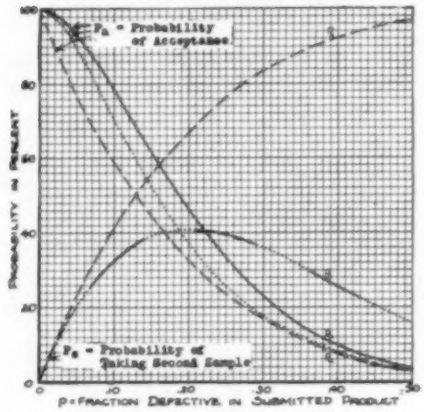

P_a = Probability of Acceptance
P_s = Probability of Taking Second Sample
Probability in Percent
p = Fraction Defective in Submitted Product

CHART 4B April 28, 1948

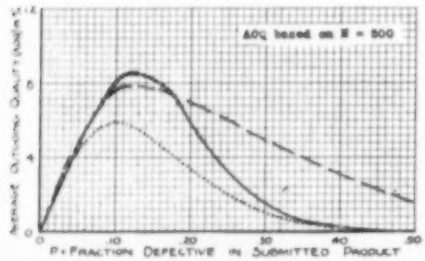
NORMAL TESTING: LOT SIZE, N = 301-500

AQL = 6%: $n_1 = 15$, $n_2 = 15$; $c_1 = 1$, $c_2 = 4$ } c_2 applies to $n_1 + n_2$

AQL = 3%: $n_1 = 15$, $n_2 = 15$; $c_1 = 1$, $c_2 = 2$ } c_2 applies to $n_1 + n_2$

JAN: $n_1 = 5$, $n_2 = 100$; $c_1 = 0$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6% ····· AQL = 3% — — JAN Plan



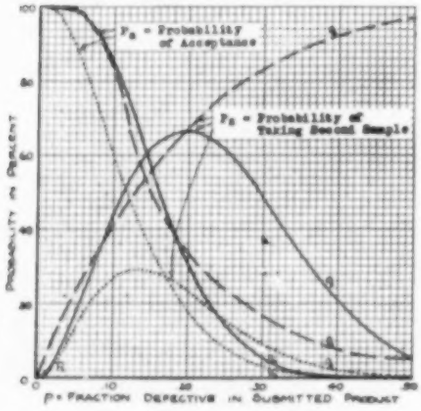

P_a = Probability of Acceptance
P_s = Probability of Taking Second Sample
Probability in Percent
p = Fraction Defective in Submitted Product

CHART 5 April 28, 1948

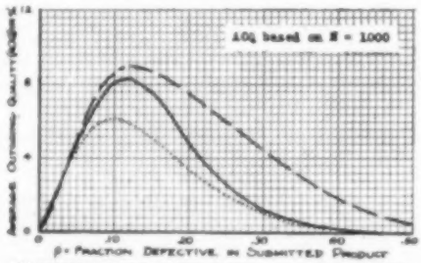
NORMAL TESTING: LOT SIZE, N = 501-1,000

AQL = 6%: $n_1 = 15$, $n_2 = 25$; $c_1 = 1$, $c_2 = 5$ } c_2 applies to $n_1 + n_2$

AQL = 3%: $n_1 = 15$, $n_2 = 25$; $c_1 = 1$, $c_2 = 3$ } c_2 applies to $n_1 + n_2$

JAN: $n_1 = 10$, $n_2 = 100$; $c_1 = 1$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6% ····· AQL = 3% — — JAN Plan



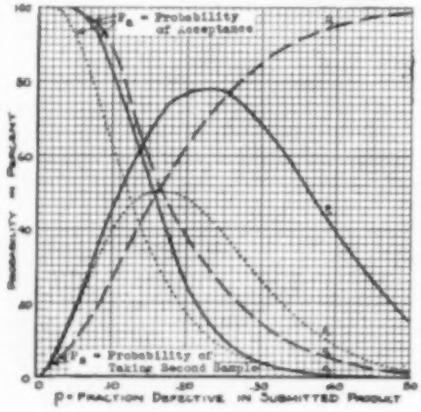

P_a = Probability of Acceptance
P_s = Probability of Taking Second Sample
Probability in Percent
p = Fraction Defective in Submitted Product

CHART 6 April 28, 1948

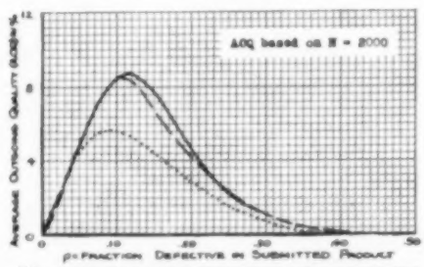
NORMAL TESTING: LOT SIZE, N = 1,001-2,000

AQL = 6%: $n_1 = 18$, $n_2 = 30$; $c_1 = 1$, $c_2 = 6$ } c_2 applies to $n_1 + n_2$

AQL = 3%: $n_1 = 18$, $n_2 = 30$; $c_1 = 1$, $c_2 = 3$ } c_2 applies to $n_1 + n_2$

JAN: $n_1 = 20$, $n_2 = 100$; $c_1 = 2$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6% ····· AQL = 3% — — JAN Plan



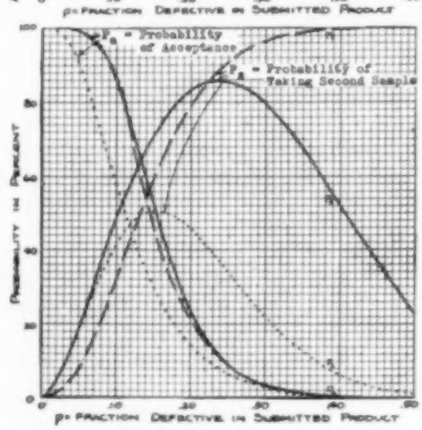

P_a = Probability of Acceptance
P_s = Probability of Taking Second Sample
Probability in Percent
p = Fraction Defective in Submitted Product

CHART 2 April 26, 1945

NORMAL TESTING: LOT SIZE, N = 51-100

AQL = 6½: $n_1 = 7$, $n_2 = 14$; $c_1 = 0$, $c_2 = 2$ } c_2 applies to $n_1 + n_2$

AQL = 2½: $n_1 = 7$, $n_2 = 14$; $c_1 = 0$, $c_2 = 1$ } $n_1 + n_2$

JAN: $n = 5$, $c = 0$

CODE: —— AQL = 6½; ····· AQL = 2½; — — JAN Plan

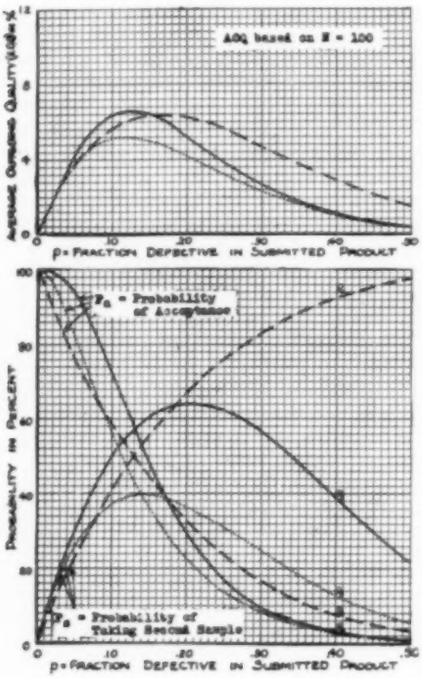

AOQ based on N = 100
Average Outgoing Quality (AOQ) in %
p = Fraction Defective in Submitted Product
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
Probability in Percent

CHART 3 April 26, 1945

NORMAL TESTING: LOT SIZE, N = 101-200

AQL = 6½: $n_1 = 8$, $n_2 = 16$; $c_1 = 0$, $c_2 = 3$ } c_2 applies to $n_1 + n_2$

AQL = 2½: $n_1 = 8$, $n_2 = 16$; $c_1 = 0$, $c_2 = 2$ } $n_1 + n_2$

JAN: $n_1 = 5$, $n_2 = 100$; $c_1 = 0$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6½; ····· AQL = 2½; — — JAN Plan

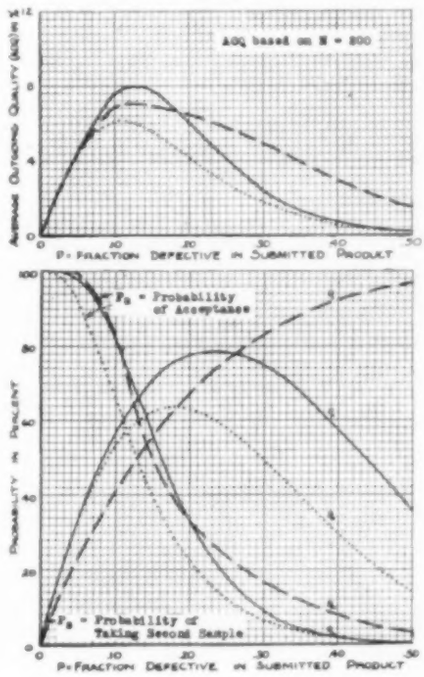

AOQ based on N = 200
Average Outgoing Quality (AOQ) in %
p = Fraction Defective in Submitted Product
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
Probability in Percent

CHART 4A April 26, 1945

NORMAL TESTING: LOT SIZE, N = 201-500

AQL = 6½: $n_1 = 10$, $n_2 = 20$; $c_1 = 0$, $c_2 = 4$ } c_2 applies to $n_1 + n_2$

AQL = 2½: $n_1 = 10$, $n_2 = 20$; $c_1 = 0$, $c_2 = 2$ } $n_1 + n_2$

JAN: $n_1 = 5$, $n_2 = 100$; $c_1 = 0$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6½; ····· AQL = 2½; — — JAN Plan

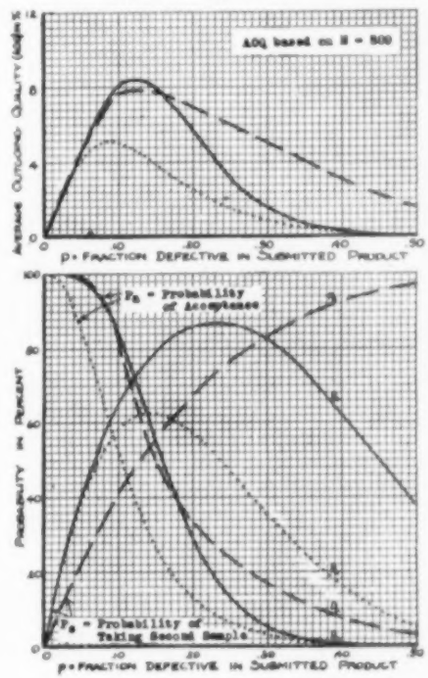

AOQ based on N = 500
Average Outgoing Quality (AOQ) in %
p = Fraction Defective in Submitted Product
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
Probability in Percent

CHART 7 April 26, 1945

NORMAL TESTING: LOT SIZE, N = 2,001-5,000

AQL = 6½: $n_1 = 18$, $n_2 = 36$; $c_1 = 1$, $c_2 = 7$ } c_2 applies to $n_1 + n_2$

AQL = 2½: $n_1 = 18$, $n_2 = 36$; $c_1 = 1$, $c_2 = 4$ } $n_1 + n_2$

JAN: $n_1 = 80$, $n_2 = 100$; $c_1 = 2$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6½; ····· AQL = 2½; — — JAN Plan

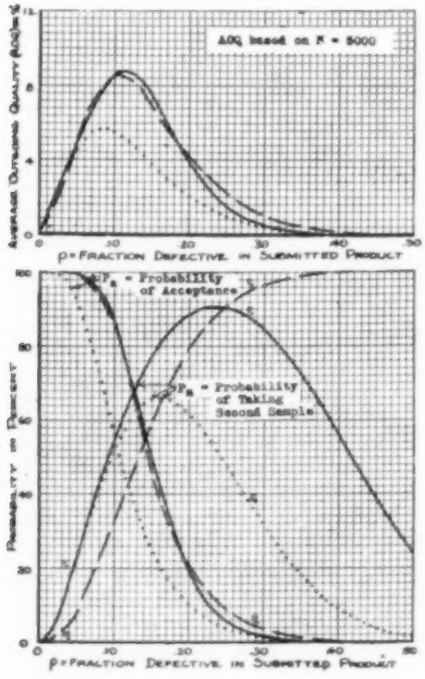

AOQ based on N = 5000
Average Outgoing Quality (AOQ) in %
p = Fraction Defective in Submitted Product
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
Probability in Percent

CHART 8 April 26, 1945

NORMAL TESTING: LOT SIZE, N = 5,001-10,000

AQL = 6½: $n_1 = 80$, $n_2 = 45$; $c_1 = 1$, $c_2 = 8$ } c_2 applies to $n_1 + n_2$

AQL = 2½: $n_1 = 80$, $n_2 = 45$; $c_1 = 1$, $c_2 = 4$ } $n_1 + n_2$

JAN: $n_1 = 80$, $n_2 = 100$; $c_1 = 2$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6½; ····· AQL = 2½; — — JAN Plan

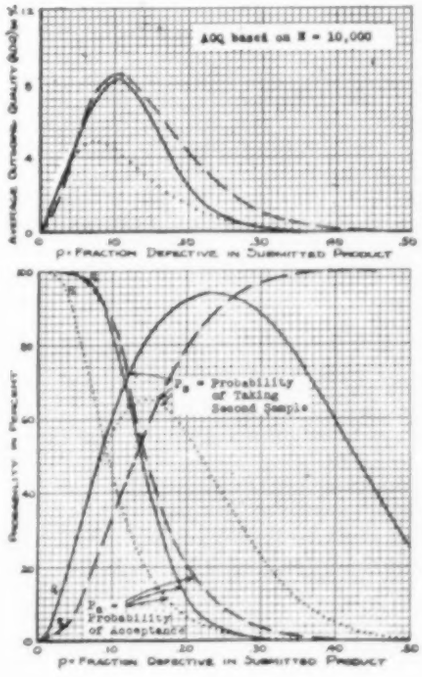

AOQ based on N = 10,000
Average Outgoing Quality (AOQ) in %
p = Fraction Defective in Submitted Product
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
Probability in Percent

CHART 9 April 26, 1945

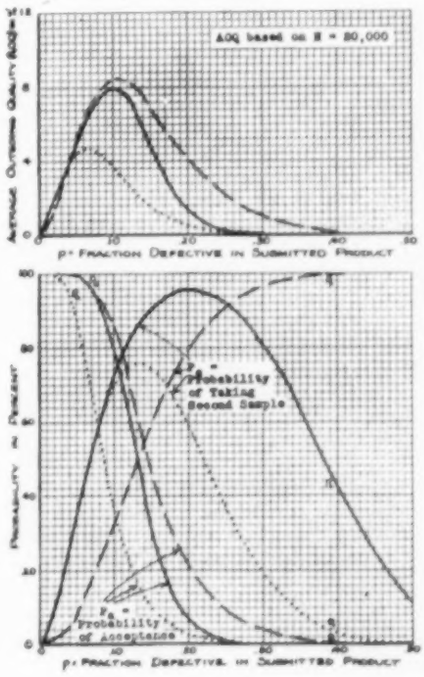
NORMAL TESTING: LOT SIZE, N = Over 10,000

AQL = 6½: $n_1 = 85$, $n_2 = 50$; $c_1 = 1$, $c_2 = 9$ } c_2 applies to $n_1 + n_2$

AQL = 2½: $n_1 = 85$, $n_2 = 50$; $c_1 = 1$, $c_2 = 5$ } $n_1 + n_2$

JAN: $n_1 = 80$, $n_2 = 100$; $c_1 = 2$, $c_2 = 10$ } c_2 applies to n_2 only

CODE: —— AQL = 6½; ····· AQL = 2½; — — JAN Plan


AOQ based on N = 20,000
Average Outgoing Quality (AOQ) in %
p = Fraction Defective in Submitted Product
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
Probability in Percent

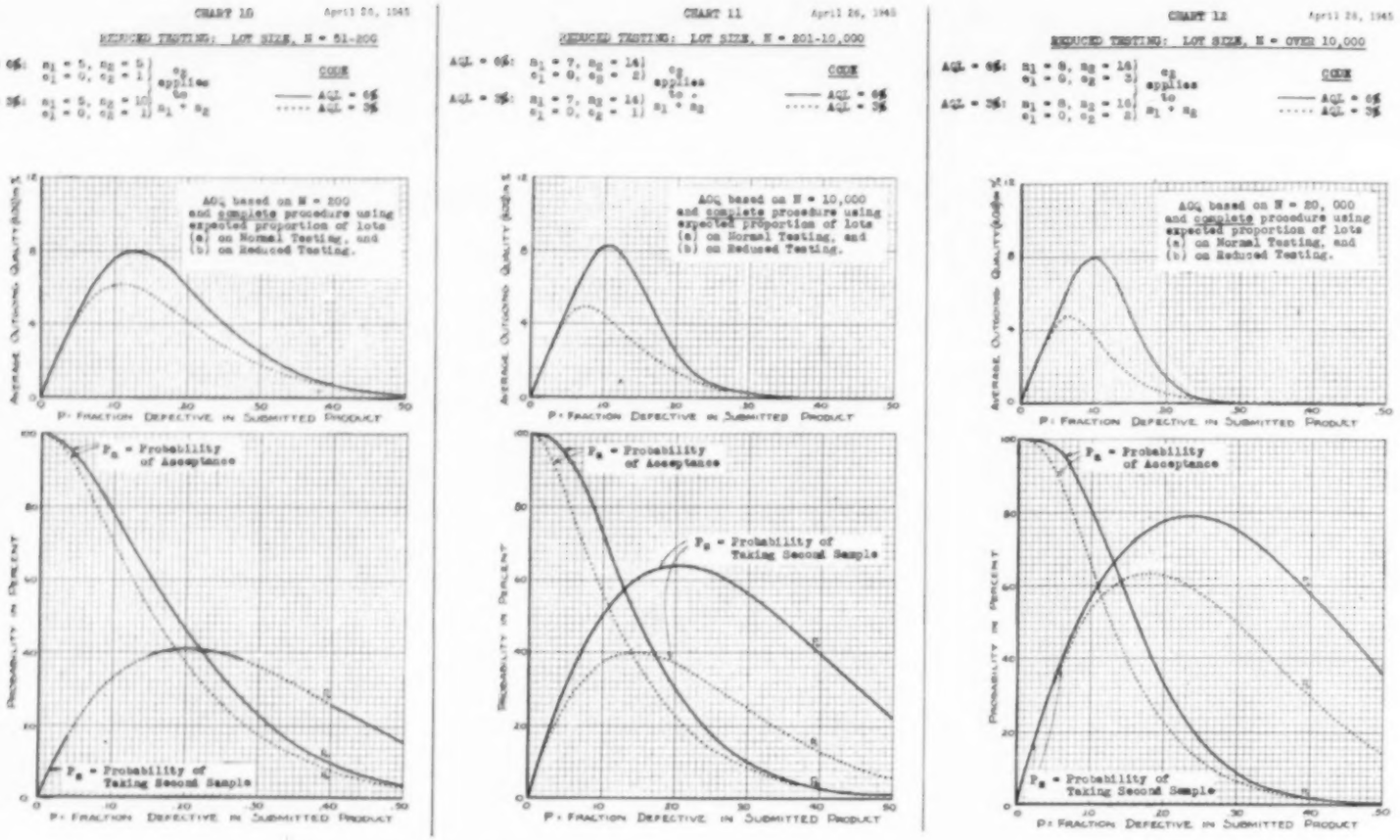


CHART 10
April 26, 1945
REDUCED TESTING: LOT SIZE, N = 51-200
AQL = 6%: $n_1 = 5$, $n_2 = 5$, $c_1 = 0$, $c_2 = 1$
AQL = 3%: $n_1 = 5$, $n_2 = 10$, $c_1 = 0$, $c_2 = 1$
$n_1 + n_2$
CODE
AQL = 6%
AQL = 3%
AOQ based on N = 200 and complete procedure using expected proportion of lots (a) on Normal Testing, and (b) on Reduced Testing.
AVERAGE OUTGOING QUALITY (PERCENT)
P: FRACTION DEFECTIVE IN SUBMITTED PRODUCT
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
PROBABILITY IN PERCENT
CHART 11
April 26, 1945
REDUCED TESTING: LOT SIZE, N = 201-10,000
AQL = 6%: $n_1 = 7$, $n_2 = 14$, $c_1 = 0$, $c_2 = 2$
AQL = 3%: $n_1 = 7$, $n_2 = 14$, $c_1 = 0$, $c_2 = 1$
$n_1 + n_2$
CODE
AQL = 6%
AQL = 3%
AOQ based on N = 10,000 and complete procedure using expected proportion of lots (a) on Normal Testing, and (b) on Reduced Testing.
AVERAGE OUTGOING QUALITY (PERCENT)
P: FRACTION DEFECTIVE IN SUBMITTED PRODUCT
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
PROBABILITY IN PERCENT
CHART 12
April 26, 1945
REDUCED TESTING: LOT SIZE, N = OVER 10,000
AQL = 6%: $n_1 = 8$, $n_2 = 16$, $c_1 = 0$, $c_2 = 2$
AQL = 3%: $n_1 = 8$, $n_2 = 16$, $c_1 = 0$, $c_2 = 1$
$n_1 + n_2$
CODE
AQL = 6%
AQL = 3%
AOQ based on N = 20,000 and complete procedure using expected proportion of lots (a) on Normal Testing, and (b) on Reduced Testing.
AVERAGE OUTGOING QUALITY (PERCENT)
P: FRACTION DEFECTIVE IN SUBMITTED PRODUCT
P_a = Probability of Acceptance
P_2 = Probability of Taking Second Sample
PROBABILITY IN PERCENT

Estimation of Optimum Sample Size in Destructive Testing by Attributes

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Every manufacturing operation produces some proportion of material which does not conform with the specification requirements defining an acceptable product. The proportion of defective items in the product may be determined by testing each item in the lot. Such 100-per cent inspection is usually unnecessary or undesirable and frequently impossible, as in the case of destructive testing.

Absolute certainty as to the quality of a given lot of product can result only from 100-per cent inspection. Anything less than total inspection will yield less-than-certain information regarding the quality of product. Where 100-per cent testing can be or must be avoided, it is necessary to resort to testing samples representative of the manufactured product. However, a sample almost invariably differs from the quality of the lot from which it was taken. The smaller the sample the more uncertain is the estimate of the true quality of the lot.[1]

Within certain limits, uncertainty as to the true quality of a lot can be tolerated, that is, it is usually not important to know the exact percentage of defectives in a lot, an approximation being sufficient. The limits to be set on the degree of approximation are governed by the grade of product made by the manufacturer and by the grade desired by the purchaser. The more perfect the product, the more expensive it is to make—a fact recognized by both producer and purchaser. Hence the puchaser expects a certain proportion of defective material. A sampling scheme must be devised which will keep testing at a minimum while insuring, within limits, that a certain proportion of defectives is not exceeded.

The phrase "within limits" may be explained as follows. When a sampling system is introduced in a specification, a certain number of items must be inspected, and not more than a stated number of defectives will be tolerated. Due to sampling fluctuations, a certain probability exists that a good lot may be rejected and, likewise, a probability exists that a poor lot may be accepted. When the sample size, permissible number of defectives, and the greatest tolerable per cent defective are assigned, the probabilities of acceptance

or rejection of lots of any given quality may be calculated.

Interested parties, then, must strike a balance between two major opposing factors. First, they must decide how much uncertainty they care to tolerate in estimating the quality of product. Second, the cost of inspection must be reduced to a practicable minimum. But to reduce uncertainty, the sample size must be large; to reduce inspection costs, the sample size must be small. It is possible to achieve an equilibrium between these factors by recognizing that uncertainty of estimation of lot quality represents a definite cost factor.

When testing is non-destructive, the Dodge-Romig Lot Tolerance Per Cent Defective tables require 100-per cent inspection of the lot whenever the sample shows more than the allowable number of defectives. Consequently, when a good lot is rejected, due to the calculable probability of taking an unfavorable sample, the total amount of inspection is greatly increased. It is therefore important and practicable to compute the optimum sample size which will reduce to a minimum the total testing done, both on the samples and in detailed inspection of rejected lots.[2]

In destructive testing, or in non-destructive tests where the cost of 100-per cent inspection of rejected lots is prohibitive, the disposition of lots is decided on the basis of the sample alone. Nevertheless, it is possible to compute an optimum sample size which will reduce to a minimum the total cost, not only of the samples and testing, but also lots, many or all of which may be good lots, that happen to yield unfavorable samples.

It will be helpful to use an example to indicate how this may be accomplished. It is found that a given product can be used economically provided not over 7 per cent of the product is defective. The test to determine if the item is defective is destructive, precluding the possibility of 100-per cent testing of a rejected lot. (These considerations would also apply to a lot consisting of items of such low value that the cost of 100-per cent inspection, even non-destructive testing, would be prohibitive in relation to the total value of the lot.) The prospective purchaser agrees to accept the product under a sampling scheme such that he would take only one chance in ten (Consumer's Risk = 0.1) of accepting lots which contain 7 per cent of defective material. In other words, the purchaser, realizing that the certainty bred of 100-per cent testing is impossible in this case, is willing to take a calculated risk (one chance in ten) of accepting a lot containing 7 per cent defective (Lot Tolerance Per cent Defective). He requires that a sampling system be set up such that the acceptance requirements for a given sample size will be met not oftener than one time in ten by a lot containing the lot tolerance per cent defective.

Suitable tables and charts have been prepared [2], [3], [4] from which the relationship between the probability of occurrence of c defectives, the sample size, n, and the lot tolerance fraction defective, p_t, may be determined. In this particular example, p_t has been set at .07 (corresponding to 7 per cent defective), and the probability of finding c or less defectives in a sample of n (Consumer's Risk or the probability of accepting material of tolerance quality) has been set at .10. In the chart[2] with $p_t = .07$, the number n, in the sample may be computed for each of the several pn numbers corresponding to the related c numbers. When these figures are tabulated, as in Table I, the result is a series of sample sizes, n, and corresponding allowable numbers of defectives, c, such that the probability is .10 (one chance in ten) of accepting lots of tolerance quality.

Table I: Values of $p_t n$ and n Obtained from the Poisson Chart or Tables When $p_t = .07$

c	$p_t n$	n
0	2.3	33
1	3.9	56
2	5.3	76
3	6.7	96
4	8.0	114
5	9.3	133
6	10.5	150
7	11.8	169
8	13.0	186
9	14.2	203
10	15.5	221
.	.	.
.	.	.
.	.	.

Note: These values are based on the Poisson Exponential, a suitable approximation for computing the Consumer's Risk when p does not exceed .10 and when the sample is not over 10 per cent of the lot. (See Reference 2, page 43.)

Insofar as the purchaser is concerned, any set of n and c numbers given in Table I will afford the desired protection against acceptance of lots of tolerance quality ($p_t = .07$). It remains to decide which of the several sets of n and c numbers shall be specified. It might be thought that, since a sample of 33 items will afford the purchaser the same protection as will a sample of 56 or 76, the smaller sized sample should be taken for test. It must be borne in mind, though, that the n and c sets in Table I protect the purchaser against lots of quality, $p_t = .07$, only. If the manufacturer submits lots of tolerance quality, only one in every ten such lots will be accepted by the purchaser. Obviously the manufacturer must submit lots of a quality considerably better than tolerance quality to stay in business. However, the probability that a lot of given quality will pass the requirements established by any set of n and c given in Table I will depend upon the quality of the lot. Even if the quality is much better than tolerance quality ($p_t = .07$), the manufacturer takes a certain risk that his product may be rejected occasionally due to misrepresentation of the lot by a small sample. For this reason, the smaller sample may result in a penny-wise, pound-foolish specification.

Suppose the manufacturer, over a period of time, has produced material containing an average of 2 per cent defective. This is called the Process Average. The probability that a lot produced by such a process will be rejected is called the Producer's Risk, P_p, and is equal to $1 - P_a$, where P_a, the probability of acceptance, is the probability of finding c or less defectives in a sample of n from the lot whose quality may be represented by $\bar{p}$, the Process Average Fraction Defective. It is important to recognize that the Producer's Risk represents a definite cost factor because it represents the chance of having an acceptable lot rejected, resulting in loss to the manufacturer.

To decrease the Producer's Risk it is necessary to increase the sample size, which will raise the cost of testing. It is necessary, therefore, to ascertain which of the paired n and c numbers, given in Table I, will reduce to a minimum

the sum of the inspection cost and the calculable cost due to the Producer's Risk.

If each test costs $15, including the cost of the sample destroyed, the total cost, C_t, of running all the tests may be computed for sample size n. To compute the loss due to the Producer's Risk, it is necessary to know the size of the lot and the reclaim or salvage value, if any, of the rejected item. Table II was computed on the basis of a lot size of N = 5000 and an estimated salvage value of $3 on a $5 item. In Table II, the columns headed by n and c are taken from Table I and represent the related sample sizes and allowable number of defectives corresponding to a lot tolerance fraction defective of p_t = .07 and a Consumer's Risk = .10. The process average fraction defective, $\bar{p}$ = .02, is multiplied by each n to give $\bar{p}n$. The same chart or table used in computing Table I will give P_a, the probability of acceptance (finding c or less defects) for each pair of c and $\bar{p}n$ numbers. The probability of rejecting a lot, or Producer's Risk, Pp, is equal to $1-P_a$. N—n gives the number of items in the lot which are not used in testing and which are subject to acceptance or rejection. The product of (N—n) by Pp gives N_r which represents the number of items which may be rejected, in the long run, due to unfavorable misrepresentation of the lot by the sample. If the item is worth $5, with salvage value of $3, then the estimated cost of rejection, C_r, is ($5 — $3) multiplied by N_r. The sum of the corresponding costs of testing, (C_t) and of rejection, (C_r), gives the total anticipated cost per lot of the sampling system represented by the corresponding n and c numbers.

It is noteworthy that, up to c = 10, the highest total cost is associated with the two smallest sample sizes. The lowest cost corresponds to the sample size of 114, allowing not more than 4 defectives. Except for lots of very low process average fraction defective (high quality), it will be found that the optimum sample size will be other than the smallest.

TABLE II

c	n	$\bar{p}n$	P_a*	P_p	N-n	N_r	C_r	C_t	Total
0	33	0.66	0.51	0.49	4967	2434	$4868	$ 495	$5363
1	56	1.12	.69	.31	4944	1533	3066	840	3906
2	76	1.52	.80	.20	4924	985	1970	1140	3110
3	96	1.92	.87	.13	4904	638	1276	1440	2716
4	114	2.28	.919	.081	4886	396	792	1710	2502
5	133	2.66	.946	.054	4867	263	526	1995	2521
6	150	3.00	.966	.034	4850	165	330	2250	2580
7	169	3.38	.978	.022	4831	106	212	2535	2747
8	186	3.72	.986	.014	4814	67	134	2790	2924
9	203	4.06	.9911	.0089	4797	43	86	3045	3131
10	221	4.42	.9941	.0059	4779	28	56	3315	3371

*Obtained from the chart, Reference 2; or tables, Reference 3.

From the example given, it is clearly false economy to set up test procedures on the premise that the smaller the sample size, the less the cost. This is true with respect to the cost of inspection, but there may be a much larger cost involved, either to the producer in the form of rejected lots or in service costs, or to the consumer in terms of poor-quality goods or in inconvenience due to failure. It may be argued that many of the quantities, assumed in the example given, are not usually known with accuracy, but it will be found that any reasonable, intelligent estimate of the factors involved will be sufficient for the purpose. As a protection for both producer and consumer, it is to their mutual advantage to devise adequate sampling systems designed to reduce the total cost of inspection and rejection to a practicable minimum.

SUMMARY. A method is presented for computing the optimum sample size in inspection (Lot Tolerance per cent Defective) where 100-per cent testing is impossible, as in destructive testing, or impracticable, when the cost of 100-per cent inspection, relative to the value of the lot, is prohibitive. An example is given covering a single-sampling system. A double-sampling scheme which allows a retest if the first sample fails, although more complex, may be computed by a parallel procedure. Or again, a multiple or sequential[5] scheme which permits many samples before a decision is reached can be subjected to the same treatment. It is shown that when the producer or the consumer takes advantage of pertinent manufacturing data (e.g., the process average fraction defective, cost per item, salvage value, etc.), sound, economical sampling systems can be established which will effect substantial savings as well as a more uniformly regulated product.

REFERENCES—

1. "An Engineers' Manual of Statistical Methods," Col. Leslie E. Simon, John Wiley and Sons (1942).
2. "Sampling Inspection Tables," Harold F. Dodge and Harry G. Romig, (Cumulative probability curves — Poisson exponential, facing p.44), John Wiley and Sons (1944).
3. "Poisson's Exponential Binomial Limit," E. C. Molina, D. Van Nostrand Company 1942).
4. "Table of the Incomplete B-Function," Karl Pearson, "Biometrika," London.
5. "Sequential Sampling Inspection for Attributes," H. A. Freeman, "Industrial Quality Control," September 1945, pp.3-7.

LOCAL SOCIETY REPORTS

Ohio Quality Control Society

The first meeting of the 1946-1947 season was held at the Cleveland Engineering Society, Friday, September 27, 1946. An informal dinner preceded the business meeting. The guest speaker, Mr. Frederick J. Halton, Jr., presented the subject "How Quality Control is Presented to Top Management."

The President of the Society announced that meetings have been scheduled for the second Friday of each month and that these meetings will be held at the Cleveland Engineering Society in Cleveland. It was also announced that Professor D. K. Wright, Jr., has completed an educational program for use in conjunction with the Ohio Quality Control Society. Educational meetings will be held once a month, probably on a date midway between the scheduled meetings.

American Society for Quality Control Georgia Section

The Atlanta Quality Control Society met on October 11 at the Georgia School of Technology. Dr. Ralph Hefner, Dean of General

Studies, gave a paper on "Sequential Sampling."

At the business meeting, a Constitution was adopted and the name for this group changed to "American Society for Quality Control-Georgia Section."

At the dinner session, Mr. W. E. Crooks of the Celanese Corporation of America, Tubize Division, gave a talk on "Some Management Notes on Quality Control."

Philadelphia Chapter American Society for Quality Control

"Quality Control in Spring Manufacture" was the subject of Mr. F. C. Schulze's talk on September 20. A typical control chart procedure as used by Hunter Pressed Steel Company provides for taking five springs at 15 minute intervals and plotting results of a load test. After heat-treatment, another set of samples is taken and results plotted on another chart. A sample of five springs each hour is taken at the point of 100% inspection. Finally, before packing, a frequency distribution of 100 springs is made from each box.

Control chart plotting is expedited by the use of an adding machine. After the order, part number, date, time, and inspector's clock number are recorded on the tape as non-add numbers, the five observed values of a group are recorded and a sub-total registered. This sub-total is entered in the machine again and the grand total recorded. The average is then obtained by moving the decimal one place to the left. The maximum of the five values is then recorded and the minimum subtracted giving the range. This procedure is followed for each group. The tape then forms a permanent record.

Future meetings have been scheduled as follows: December 13, Applications of Quality Control by Statistical Methods, William J. Masser, General Electric Company; January 16, The Significance of Modern Quality Control to Management, A. I. Peterson, Manager, Quality Control Department, R. C. A.; February 21, The Difference Control Chart with an Example of its Use, Major Frank E. Grubbs, Aberdeen Proving Ground.

Milwaukee Society for Quality Control

The first regular meeting of the fall was held September 9, 1946, at the Red Arrow Club, Milwaukee, Wisconsin.

Mr. Frederick J. Halton, Jr., Assistant to the President, John Deere and Company, spoke on the subject, "Introducing Quality Control to Management." He covered such items as chance distribution, limits for control charts and their application in controlling quality. He cited numerous examples of saving effected by controlling quality during the manufacturing cycle and suggested the value of control chart techniques in other than manufacturing operations.

"A Training Program for Quality Control Personnel" was the subject of the October 14 meeting at the Red Arrow Club. Mr. Henry Becker, a member of the Chicago Society for Quality Control, was the speaker.

The Delaware Quality Control Society

At the September 5 meeting, Mr. W. L. MacKinnon presented a brief discussion of an approximate empirical formula for a factor to be used in estimating the standard deviation

$$s = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$$

from $\bar{R}$. The equation is $s_R = \bar{R}.f.$, where $f = (n+3)/4n$. Use of this formula with actual data for n varying from 3 to 6 produced estimates whose deviations from s averaged only 1 per cent, and the greatest deviation of a single estimate was 9 per cent. It is believed that the equation is valid up to $n = 10$ and since it is simple to use and easy to remember, it is recommended as a short cut method for calculating s in samples of less than 10. It should be emphasized that the equation is to be used only for estimating s as defined above.

At the October 3 meeting, Mr. Daniel Wray, Quality Control Analyst for SKF, gave an extremely interesting talk on the application of quality control methods to the manufacture of bearings at SKF. He discussed their experience with sequential sampling and mentioned their method of dealing with inspector inconsistencies. He emphasized the fact that commercial tolerances set too tightly may be as bad as tolerances that are too loose, due to excess amount of scrap and, even more important, due to the eventual loss of confidence, by the production men, in the principles of quality control.

Society for Quality Control Northeastern Indiana

The meetings of the Society will be held the second Wednesday of each month. At the September 11 meeting, Mr. Harry B. Marsh spoke on "The Use of Statistics in Forecasting Market Demand." At the October 9 meeting, Mr. Charles A. Bicking, Hercules Powder, spoke on "Quality Control in the Chemical Industry." The November 13 meeting will be held at the plant of the International Harvester Company.

The Society is sponsoring a Beginners Course in Quality Control conducted by Mr. Keith E. Ross, General Electric Company.

Society for Statistical Quality Control—Metropolitan New York Section

Mr. A. I. Peterson was Chairman of the October 22 meeting at which Mr. W. R. Pabst, Bureau of Ordnance, Navy Department, Washington, D. C., presented "Installing Quality Control at a Navy Establishment," and Mr. W. A. Bradof, R. C. A. Victor Division, Harrison, New Jersey, presented "Examples of Quality Control in Electron-Tube Manufacturing."

Mr. A. G. Ashcroft, Alexander Smith and Sons Carpet Company, was Chairman of the November 22 meeting at the Engineering Building in New York. The following program was presented: Mr. John C. Hintermaier, Vanity Fair Mills, "Process Control in Textiles;" Mr. Fred Noechel, Botany Worsted Mills, "Statistical Quality Control Methods as Used in the Textile Industry;" Mr. Harry Schoenfelder, Philadelphia Q.M.C., "Inspection of Textiles;" Mr. David Schwartz, New York Q.M.C., "Inspection of Fabricated Textile Items."

At the next meeting at the Robert Treat Hotel, Newark, December 13, Professor S. S. Wilks, Princeton University, will speak on "Research and Training for Industrial Statistics." The following day, Saturday, December 14, a joint meeting of the Delaware, Philadelphia, and Metropolitan Sections will be held at Princeton. The session begins at 9:45 A.M. with a welcoming address by Dean Kenneth H. Condit, Princeton School of Engineering, after which two parallel sessions will be held; one devoted to "Analysis of Variance" and the other to "Process Control." Mr.

George D. Edwards, Bell Laboratories, President of the American Society for Quality Control, will address the luncheon meeting on "General Aspects of Quality Control." At the afternoon session, Mr. G. F. Smith, Johnson and Johnson, will present "Management's Viewpoint of Quality Control."

Saint Louis Chapter American Society for Quality Control

Believing that other Society sections might be interested in gaining something from the development problems of the St. Louis Society, the secretary reports the following. Various committees have been organized during the summer months. An attempt was made to place every member on some committee. The results indicate a closely knit organization. Our membership now has reached 38 without an active drive. Twenty-two prospective members attended our September meeting. Professor Lloyd Knowler of Iowa State University spoke on "Fundamentals of Quality Control." The program for the year is being worked out to have an outside speaker at every other meeting. The intervening meetings will consist of two or three short talks on problems by members with the remaining part of the meeting used for cross discussion by all present. General interest in the profession and the Society is gaining rapidly in this section, because of our attack and eagerness to present the true beneficial features of Quality Control. We are building this section as we would a Quality Control program in a plant. With this in mind we are refraining at this time from any great amount of the statistical theory of the subject. We are also attempting to guide our activities so that all phases of Quality Control are presented—this covers not only the statistical approach, but also gages, instruments, tools, inspection methods and procedures.

Chicago Society for Quality Control

At the September 11 meeting, Mr. D. P. Walsh, Manager of the Detroit office of Magnaflux Corporation, spoke on the "Use of Magnaflux Testing." Mr. Walsh's talk covered both magnetic particle and fluorescent penetrant inspection of piece parts, sub-assemblies, and finished product for surface or subsurface defects. The meeting was attended by 95 members and guests.

The annual election of officers (conducted by mailed ballot) was announced at this meeting. The new officers are: President, E. H. Robinson, Johnson and Johnson; Vice-President, A. G. Brooks, Western Electric Company; Corresponding Secretary, H. L. Jones, Illinois Bell Telephone Company; Recording Secretary, H. R. Kellogg, Western Electric Company; Treasurer, Fred Trowbridge, Electrical Research Laboratories; Member of the Board of Directors (two year term), F. J. Halton, Jr., Deere and Company.

Plans are in progress for recommending Constitutional changes which, if adopted, will bring the Society's fiscal year in agreement with that of the American Society. Also under consideration is an amendment which will make membership in the American Society compulsory for all members of the Chicago Society.

The Society is giving a series of ten monthly lectures on "Statistical Methods for Quality Control Engineers." The first lecture on "Fundamentals of Statistical Analysis, Measurement of Dispersion and Central Tendencies," was given September 18 by Mr. H. R. Kellogg, and was attended by 150 persons, most of whom were not members of the Society. This attendance was maintained at the October 16 meeting when Mr. Fred Trowbridge dealt with "Frequency Curves, Accuracy of Measurement, and Methods of Collecting Data."

AMERICAN SOCIETY NEWS

Advisory Council Announced

Announcement is made of the composition of the Advisory Council of the American Society for Quality Control, as follows:

Dr. E. U. Condon
Director, Bureau of Standards
U. S. Department of Commerce, Washington, D. C.

Mr. M. Herbert Eisenhart
President, Bausch & Lomb Optical Co., Rochester, N. Y.

Brigadier General Hermon F. Safford
Executive Vice-President, Ohio Rubber Co., Willoughby, Ohio

Dr. Walter A. Shewhart
Member of Technical Staff, Bell Telephone Laboratories, Incorporated, Murray Hill, N. J.

Colonel Charles Deere Wiman
President, Deere & Co., Chicago

Committee on Programs and Speakers Completed

Appointment of the following Committee on Programs and Speakers is announced:

Vice-President and General Chairman:
A. I. Peterson

Executive Chairman:
Frank A. Palumbo

New England:
Gerald H. Cassady, Regional Chairman
George J. Meyers, Jr.
Joseph J. Ferri

Middle Atlantic:
Edward M. Schrock, Regional Chairman
Charles A. Bicking
Harry G. Romig

Northern:
Robert Funk, Regional Chairman
Louis F. Surridge
James A. Tilton
I. C. Kepner
Richard W. S. Freeman

Central:
Charles V. Kiimas, Regional Chairman
L. C. Sheehan
Wade R. Weaver

Midwest:
Wayne M. Bicklen, Regional Chairman
Charles W. Richard
Frank Pettit
William E. Gibbons
C. W. Lentfoehr
R. D. Long
J. L. Johnson
L. S. Kauffman

Western:
Dr. Holbrook Working, General Chairman

Committee on Relations With Other Technical Societies Completed

Appointment of the following Committee On Relations With Other Technical Societies is announced:

Vice-Pres. and General Chairman:
Andrew I. Peterson

Executive Chairman:
Harold F. Dodge

New England:
Joseph J. Ferri, Regional Chairman
L. A. Seder
R. K. Hellman

Middle Atlantic:
Dr. T. Smith Taylor, Regional Chairman
Dr. E. V. Lewis
Charles R. Scott, Jr.

Northern:
Ralph H. Houghton, Regional Chairman
J. R. Steen
Fred C. Nielson
J. P. Prosch
Bernard H. Lloyd

Central:
Earl W. Mahaney, Regional Chairman
J. W. Allquist
R. G. Kennedy, Jr.

Midwest:
A. R. Burgess, Regional Chairman
Warren E. Jones
Carl M. Noble
Carl G. Schmid
Wayne M. Bicklen
E. G. Kressin
M. C. Orchard
Niles Barnard

Western:
Dr. Preston C. Hammer, Regional Chairman

Changes in General Committees

The following changes and corrections have been made in the rosters of the General Committees as announced in the September, 1946 issue:

Committee on Publicity and Public Relations

Northern:
L. C. Tackley (addition)

Central:
James K. Kinkead (correction)

Midwest:
A. E. Bennett (correction)

Committee on Membership

Northern:
Benjamin Friedland (addition)

Committee on Relations with Educational Institutions

Northern:
George I. Basile (addition)

Joint Meeting with American Institute of Electrical Engineers

The American Society for Quality Control has accepted an invitation from the American Institute of Electrical Engineers to participate in a joint quality control conference of the Society and the Institute, to be held in connection with the Winter Convention of the Institute at the Engineering Society's Building in New York City during the week beginning 27 January, 1947.

ADVANCE NOTICE

First Annual Convention
American Society for Quality Control
and
Second Midwest Quality Control Conference
Sherman Hotel, Chicago, Illinois
Thursday and Friday, June 5 and 6, 1947

Tentative Program

June 5	Morning	Registration
		Clinics
	Noon	Joint Luncheon with Chicago Association of Commerce
	Afternoon	Clinics
	Evening	Annual Dinner of American Society for Quality Control
June 6	Morning	Clinics
	Noon	Luncheon to be arranged
	Afternoon	Clinics

A meeting of the Board of Directors of the American Society for Quality Control will be held in Chicago sometime during, or immediately following the conclusion of, the Convention, — possibly on Saturday, June 7th.

The program of Clinics will place special emphasis on actual case histories of quality control applications in a wide variety of industries.

For the benefit of the wives and other lady members of the families of Society members, who may wish to accompany them to Chicago, a special program for the entertainment of ladies is being arranged.

Technical Papers

Each local Section is being asked, through its representative on the American Society Committee on Programs and Speakers, to suggest a subject on which a member of that Section would be willing to present a paper at one of the clinics. Such suggestions should be sent to the Program Chairman, Mr. Frank A. Palumbo, at the address given below, as early as possible.

In choosing suggested papers for acceptance, the Program Committee will give preference to actual case histories of quality control applications.

Exhibit Space

Space will be available for 61 exhibitors, and will be assigned in the order in which applications are received. It is hence suggested that inquiries for space be addressed as early as possible to the Exhibits Chairman, Mr. Henry J. Becker, at the address given below.

Reservations

Restricted accommodations will limit reservations for the luncheons and Annual Dinner to 1090. Total accommodations for concurrent clinics may approximate 1500. On the basis of experience at the First Midwest Quality Control Conference in 1946, requests for reservations at the luncheons and dinner will exceed the accommodations available. This may also be true of certain of the Clinics. Reservations should accordingly be made as early as possible. Inquiries and reservations should be addressed to the General Secretary, Mr. Harold R. Kellogg, at the address given below.

Convention Committee Directory

General Chairman:	E. D. Thompson Fansteel Metallurgical Corporation 2200 Sheridan Road North Chicago, Illinois
General Secretary:	Harold R. Kellogg P.O. Box No. 1097 Chicago 90, Illinois

(continued)

Arrangements Chairman:	C. W. Richard Johnson and Johnson 4949 West 65th Street Chicago 38, Illinois
Exhibits Chairman:	Henry J. Becker American Steel and Wire Co. Waukegan, Illinois
Financial Chairman:	Fred Trowbridge Sentinel Radio Corporation Evanston, Illinois
Proceedings Chairman:	Mason E. Wescott Northwestern University Evanston, Illinois
Program Chairman:	Frank J. Palumbo Palumbo and Associates 855 Board of Trade Bldg. 141 West Jackson Blvd. Chicago 4, Illinois
Publicity Chairman:	E. H. Robinson Johnson and Johnson 4949 West 65th Street Chicago 38, Illinois
Reception Chairman:	Lloyd A. Knowler University of Iowa Iowa City, Iowa
Registration Chairman:	Arthur Bender Delco-Remy Division General Motors Corporation Anderson, Indiana

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General Planning

All General and Executive Chairmen of American Society General Committees are urged to be in touch promptly with the appropriate Convention Committee Chairmen listed above, to coordinate their several activities and to make sure that the American Society General Committees lend every assistance to the Convention Committee in assuring the success of the Convention.

It is assumed that Regional and Section Chairmen will dovetail the Convention into their programs in such a way as to avoid conflicting dates, etc.

Announcement of further plans and details in connection with the Convention will appear in the January issue of INDUSTRIAL QUALITY CONTROL.

Executive Committee Meets

The Executive Committee of the American Society for Quality Control held a nine-hour meeting at the University of Buffalo in Buffalo, N. Y., on 28 September, 1946. Present were Messrs: George D. Edwards, Chairman; Ralph E. Wareham, Secretary; Martin A. Brumbaugh, Alfred L. Davis, Frederick J. Halton, Jr., Charles J. Hudson, Paul S. Olmstead, Wade R. Weaver and Alfred J. Winterhalter.

The Executive Secretary reported that the membership had passed the one thousand mark, and the Treasurer reported a balance on hand in excess of $2,950. The Chairman of the Editorial Board gave a general statement covering the operations of the Society's magazine. All of these reports were accepted as presented.

Incorporation

The President reported that incorporation of the Society under the laws of the State of New York had been completed and that its Corporate Charter had been received.

Committee on Constitution and By-Laws

As its Chairman, Mr. Halton reported that the Committee had worked out plans for a complete revision of the Constitution and By-Laws, and that a suitable division of the work among the several Committee members had been made.

(Continued in the January Issue)

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